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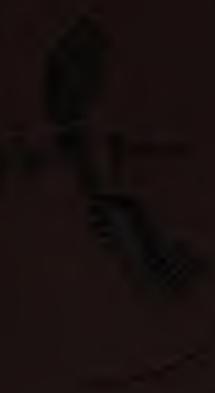
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ELECTRIC LIGHT
ITS PRODUCTION AND USE

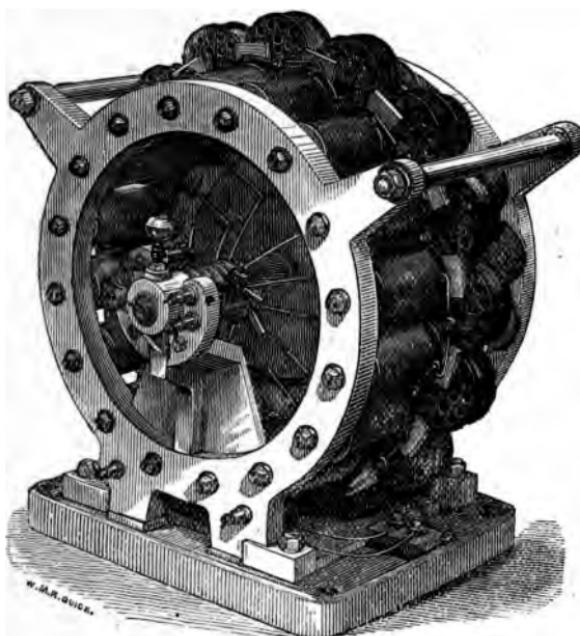
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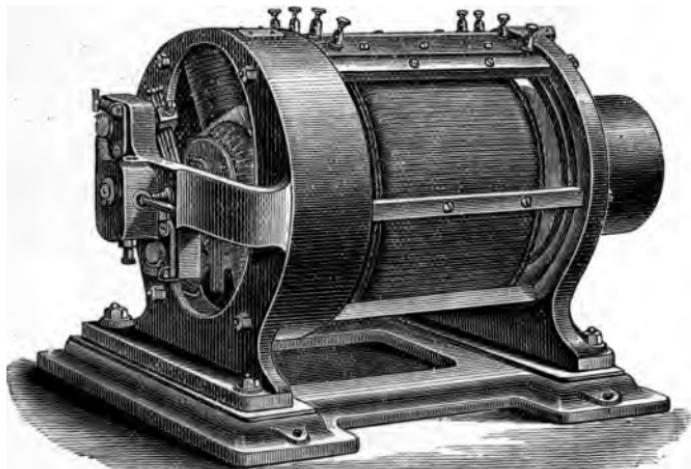
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Siemens' Twelve-light Alternating Current Machine, as used at the
British Museum. [See p. 124.]



Gramme's Combined Exciting and Dividing Machine. [See p. 113.]

ELECTRIC LIGHT

ITS PRODUCTION AND USE

EMBODYING

PLAIN DIRECTIONS FOR THE WORKING OF
GALVANIC BATTERIES, ELECTRIC LAMPS,
AND DYNAMO-ELECTRIC MACHINES

BY J. W. URQUHART, C.E.

AUTHOR OF "ELECTRO-PLATING: A PRACTICAL HANDBOOK"

EDITED BY

F. C. WEBB, M.I.C.E., M.S.T.E.

WITH NINETY-FOUR ILLUSTRATIONS



LONDON

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PREFACE.

THE following pages contain a general account of the means adopted in producing electric light. The author's intention was originally to speak only of electric light as obtained from voltaic or galvanic batteries. But the rapid development of other and more generally applicable methods has induced him to extend the limits of the work, and to treat at some length, from a practical point of view, of the dynamo-electric machine in several of its forms. Of electric lamps and other apparatus used in connection with dynamo-electric machines, the book contains several examples.

No attempt has been made to teach the science of electricity, but in the first portion of the book such particulars of the voltaic battery as may lead to a correct idea of its use for electric light production have been given. The work is, moreover, not designed for a text-book, and the author makes no pretension to teach electricians the art or science of electric lighting; but it is hoped that some portions of its contents may be read with advantage by many persons engaged in

producing electric light. Practically considered, the art of electric lighting is of such recent date that the whole subject is as yet only partially developed and understood. On account of this, and in view of the imperfections and shortcomings of his work, necessarily due to the same cause, the author asks for the kind forbearance of his readers. He has to acknowledge having received able assistance from Mr. F. C. Webb, member of the Society of Telegraph Engineers, who kindly undertook the arrangement and supervision of the work in its progress through the press, and has made many valuable suggestions and additions.

J. W. URQUHART.

LONDON, *April*, 1880.

NOTE BY THE EDITOR.

In revising for the press Mr. Urquhart's little work, I have endeavoured to arrange the matter, where possible, in the order which appeared to me most in accordance with the history of the subject, and I have here and there made a few additions which I thought would be interesting to the reader, on historical, theoretical and experimental points.

F. C. WEBB.

PALACE CHAMBERS, BRIDGE STREET, WESTMINSTER,
April, 1880.

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ELECTRIC LIGHT.

CHAPTER I.

INTRODUCTION.

IF conductors leading from the two poles of a powerful source of electricity are made to terminate in points which are brought into contact, a light will be produced when the contact is broken; and if the source is sufficiently powerful the points, or electrodes as they are termed, can be separated to a certain distance, depending on the electro-motive force of the source, without interrupting the current of electricity, which continues across the intervening space through the conduction afforded by the heated air between them. A brilliant belt of light is produced between the electrodes, which has been termed the voltaic arc. If the pointed electrodes are made of carbon the effect is greatly increased. The light in this case is supposed by some to be partly due actually to combustion of the carbon, particles of which fly off from one carbon to the other. On the other hand it has been pointed out that the incandescence is

still more intense in a vacuum, or in any of the gases that do not support combustion, than in the ordinary atmosphere, so that the phenomenon is not to be considered as one of simple combustion. A brilliant light can also be obtained by passing powerful currents through metals of low conducting power, such as platinum, or through thin pieces of carbon. In all cases it will be found that a great resistance to the current in a small space has to be overcome by the source of electricity.

The date of the earliest production of the electric light is somewhat uncertain, but in 1810 Sir Humphry Davy, with a battery of 2,000 elements, exhibited at the Royal Institution the electric light with an arc 3 inches long between carbon points.

The following is the account given in the *Philosophical Magazine*, vol. xxxv., for Jan. to June, 1810, p. 463 :—

“In the concluding lecture at the Royal Institution, the large voltaic apparatus, consisting of 2,000 double plates of four inches square, was put into action for the first time. The effect of this combination, the largest that has ever been constructed, was, as might be expected, of a very brilliant kind.

“The spark, the light of which was so intense as to resemble that of the sun, struck through some lines of air, and produced a discharge through heated air of nearly three inches in length and of a dazzling splendour. Several bodies which had not been fused before were fused by this flame; the

new metals discovered by Mr. Tennant, iridium and the alloy of iridium and osmium, zircon, and alumine, were likewise fused; charcoal was made to evaporate, and plumbago appeared to fuse *in vacuo*; charcoal was ignited to intense whiteness by it in oxymuriatic acid gas, and volatilised in it, but without effecting its decomposition."

With regard to this, Professor Daniel, whose elegant and careful writing is still worth quoting at the present day, remarks: *—“The disruptive discharge of the voltaic battery through air is dependent upon precisely the same principles as that of the Leyden battery; but the phenomena are modified by the lower intensity, greater quantity, and perpetual renewal of the force. When passing between two charcoal points, its duration renders it the most splendid source of light which is under the command of art. When the poles of a powerful battery are gradually separated after contact, the discharge takes place through an interval which increases with the heating of the air by the ignited charcoal. With the original battery of 2,000 plates, the discharge passed through four inches of air; and with the constant battery of 70 cells the flame is much more voluminous, and extends to the distance of one inch.

“It would, however, appear that the air is not the only form of matter which is concerned in the phenomena, but that particles of the solid electrodes contribute to the general effect by convection. It

* “Chemical Philosophy,” p. 460.

is probable that the superior brilliancy of the phenomena with charcoal may be owing to the larger number of its solid particles which its small cohesion enables it to throw off in the process. The colour of the light varies with the substances between which the discharge passes. Gold leaf gives white tinged with blue; silver, a beautiful emerald green; copper, bluish white light with red sparks; lead, a purple; zinc, white fringed with red.

“The arc takes place with great brilliancy under the surface of distilled water; some electrolytic effect will at the same time occur, but the greater part of the charge will pass in a brilliant stream of light.”

For many years the light only remained a little more than a scientific toy, being occasionally used for lecture purposes, or for the illumination of the microscope; but the discovery of the means of producing electricity in large quantities from mechanical motion through the intervention of magnetism, instead of by chemical action, gave this branch of electric science a new starting-point, and at the present day electric lights on a large scale are entirely produced by currents generated by the rapid movement of insulated wires. In all arrangements for the production of the electric light we require first a source or generator of electricity; secondly, conducting wires; and thirdly, an arrangement of carbons or metals, at which the light is actually emitted, called the lamp. We shall commence, therefore, by descriptions of the generators

employed ; and as electricity from voltaic batteries was first employed for the electric light, it will be more in accordance with the history of the subject to commence by describing this means of producing electricity, notwithstanding that the production of the light by the currents produced by what may be termed electro-mechanical means, is, at the present day, of the greater importance.

We shall, however, again allude to the voltaic arc when treating of the various arrangements of lamps.

CHAPTER II.

VOLTAIC BATTERIES.

ALTHOUGH voltaic electrical generators are at present quite inapplicable to the production of an electric light to replace gas permanently, they are, nevertheless, where properly handled as the author will endeavour to explain, of the greatest use for numerous minor applications of electricity as light.

For magic-lantern exhibitions, and the working of a very great number of other optical instruments, the electric light is often absolutely necessary to secure even approximately good results, and it is at present idle to suppose that in such instances the light could as a rule be produced by means of the dynamo-electric machine, although it is probable that every lecture-room of any note will shortly provide for the use of lecturers the necessary dynamo-electric plant.

In short displays of the light, whether for purposes of pleasure-ground illumination at night or advertisement, there is as yet no better or cheaper source of the current than a properly arranged voltaic battery.

For the purposes of the photographer, who often

requires a brilliant electric light in actual portraiture, or in making enlargements, the author has devised a handy and economical adaptation of Byrne's generator, which will be found to give a light of surpassing power even from so few as 12 cells; and 6 cells may be caused to produce a light suited to ordinary work. It will be well to understand, however, that this apparatus is only fitted for the production of light during a number of minutes under 15, but in most cases no such continuance of the light will be necessary.

Rudimentary expositions of the theories and actions concerned in the working of voltaic cells will not be found in this treatise. After careful consideration, and judgments upon an extensive experience with all kinds of generators, it is but too obvious that elementary instruction of this kind is often misplaced in works having a practical bearing, and is therefore really not wanted. Almost any one, after reading the description of them, can set in action and even make use of the ordinary kinds of battery, and such as want an electric light quickly and at small cost, for some useful purpose, have again no need to know the theory of the voltaic battery, while those of a different turn of mind will find it given in any of the many excellent text-books on electricity now published.

Voltaic batteries of a type suited to the production of the electric light are few in number. The batteries that are generally employed in working

telegraphs or ringing house bells, or even in electro-plating, are all too weak for our purpose.

We require a battery of small size to supply for a short period a very energetic current of electricity. We also must have a generator that will not vary much in power during about two hours. It must be cheap at first, and its cost of working must be low, while it should not give any trouble during the time the light is required. It must not waste its materials, but give all the benefit derived from the consumption of zinc as current.

Directions for the construction of all the most suitable generators will be given, and with the help of a few carefully prepared engravings it is hoped that the subject will be made clear.

All batteries consist of one or more cells, in which are placed two substances, the one more oxidisable than the other, and acted on by acids more or less diluted. The most oxidisable substance is termed the positive element, and the other the negative element. Electricity of opposite name is believed to flow off in contrary directions in equal quantities from the surface of generation, viz., the junction of the liquid with the positive plate; but for convenience, the current is supposed to flow from the positive element through the liquid to the negative element, thence from the terminal on the negative element through the external circuit of wire, earth, or other conductor back to the terminal of the positive element. The current is supposed, therefore, to leave the battery

at the *terminal attached to the negative element*, and this terminal, or the end of any wire attached to it, is termed the *positive pole*.

In the same way the *terminal or wire attached to the positive element is termed the negative pole*.

Positive Elements.—In nearly all batteries the oxidisable metal, or positive plate or element, is of zinc, and the current is therefore produced by the slow consumption or combustion of zinc, which is, therefore, our fuel. Its cost is about fourpence per lb. The best zinc to use is that known as rolled Belgian. All such plates or cylinders should be about $\frac{3}{16}$ ths of an inch in thickness, and in electric light batteries must be amalgamated; that is, coated with a closely adherent film of mercury. Zinc, when new from the rolling mill, is greasy, and this film should be scrubbed or dissolved off with hot water and soda. To cut zinc plates to size is a more difficult matter than is generally supposed. The simplest way is to make a deep scratch at the place of separation, repeat this on the opposite side, and run mercury into the cut. This will soak nearly through in a few minutes, and the plate may be divided by bending over the edge of a table. To bend zinc plates into cylinders it is only necessary to heat them as hot as can be borne in the hands by the aid of a duster, when the bending will be easily done over a wooden roller fixed in the vice, or a mallet may be used.

A question now arises as to whether the zinc plate is to be provided with a *binding-screw*, or is it

to have a copper strap soldered to it? Binding-screws are procurable of all kinds. Some are made for soldering to zinc plates, and others for screwing upon them.

Fig. 1 shows some specimens of binding-screws, of which the smallest, with rounded head, is best suited for screwing upon plates and cylinders of zinc.

For soldering, the same screw is made with and without plain tangs. Such screws—of the first kind—are procurable at 4s. per dozen, and those of the second kind at 3s. per dozen, or singly, as

required. Conducting straps of copper should be cut from sheet, and of uniform width, with a length of 5 inches. They are usually attached to zinc cylinders, for use in Bunsen's cell. It is by far best to make a hole in the zinc and strap, and to securely rivet the latter to the cylinder. The joint should be quite firm, the copper where it touches must be *clean*, and a coating of japan or other varnish will protect the joint from corrosion.

To solder, a copper "soldering bolt" is required, with a piece of tinman's solder. The surfaces must be clean, the bolt heated to the dullest red, cleaned on the point by filing, touched with hydrochloric acid ("spirit of salt") and then with the solder,

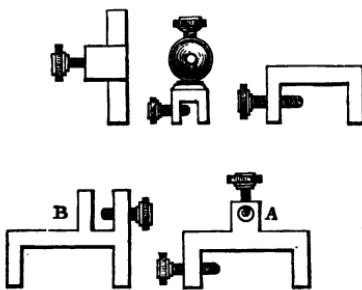


Fig. 1.—Binding-screws and Clamps.

which may also be wetted with acid. This is "tinning" the bolt. Touch the brass and zinc to be soldered together with the acid, place in position, and, taking a drop of solder on the bolt, a little care will run a good joint. The solder should perfectly amalgamate with the brass and zinc, if there is a sufficiency of heat and acid. Do not use "killed spirit," as hydrochloric acid with zinc dissolved in it is called, except for joints when zinc is absent.

To amalgamate, dip the plate for a minute in acidulated water, one to ten; pour the mercury upon a plate, and, while the zinc surface is wet, rub the mercury on with a pad of cotton or rags, or a cork, until a perfect surface is secured, and the mercury covers the plate. If there are parts where the mercury will not "take," dip the plate again into the solution and repeat, set up to drain, and go on with the remainder.

If amalgamating is not done, "local action" will reduce the current in strength and waste a great deal of the zinc. The mercury connects the hard and soft parts together, and prevents the local action from starting. After use, if the plates show black patches, they should be re-amalgamated.

Negative Plates.—Receiving or negative plates in electric light batteries are usually of the dense variety of carbon known as graphite, found in gas retorts after gas-making. It may be scaled off, and is to be had at gas-works for a mere trifle, as it is, otherwise than for batteries, of little use.

The best carbon, which assists the current, is very hard, of a grey colour and dense crystalline structure. It is, therefore, very difficult to cut, and unless proper appliances be at hand, in the shape of a revolving disc of iron, fed with silver sand and water, it will be found cheaper to buy the plates and blocks from the instrument-dealers.

Excitants are, as a rule, sulphuric acid diluted with much water. Sulphuric acid is procurable at about 3d. per pound.

Containing Cells.—The containing cells hold from half a pint to a gallon. Quart size is very well suited for electric - light batteries. The single liquid cells have only one containing pot, while those that are double have two. Outer pots may be made of glass, but, as a rule, glazed earthenware is stronger and more suitable. It will be well to mention that instrument-dealers charge as much as 1s. 6d. for containing pots, while the real cost of production is about 2d. ; and the wholesale price of ten less than 4d. For these reasons it is always best to obtain any considerable number of pots, if possible, from the manufacturer, or of wholesale houses.

Porous pots are of unglazed earthenware. They are made usually in two shapes—round tubes, long and narrow, and in oblong form, for use in Grove's battery. They are placed inside the zinc cylinder, or bent plate, and usually contain the carbon block, or plate, or, in Grove's cells, a strip of platinum foil.

Such pots, to be suitable for electric light purposes, must not be hard and dense, while the thickness of the sides should in no case be over $\frac{3}{16}$ ths of an inch. The softest are of redware; but better pots, and soft enough, are made from white clay. A test of the porosity should be taken by placing water in the pots, and allowing them to stand for some time. If, after about 15 minutes, a dew does not appear on the outside of the pot, it is probably too hard or thick, and will offer too great a resistance to the current. If, on the other hand, the water actually runs off the side, the pot is *too* porous, and will stop the action of the battery by too rapid transfusion of the liquids into each other. This mixing action is often called *endosmos*, although it is also applied to the peculiar creeping of solutions of metallic salts, such as the copper sulphate used in Daniell's cell. Porous cells are easily procurable of instrument-dealers at a cheap rate.

Composition of a Cell.—A voltaic cell must be composed of two dissimilar metals or materials immersed either in one or two liquids. The one-liquid cells, although handy enough for short experiments, so rapidly acquire a film of gas upon their plates, that all further action of the exciting liquid is put a stop to, and consequently such cells, unless agitated in some way, are unfitted for supplying current for any length of time together.

Two-liquid cells, on the other hand, cannot, on account of the porous separation, acquire a film of

gas upon their plates, and the action goes on, without the necessity for any disturbance, for a length of time dependent upon the bulk of liquids employed and the size of the plates.

Two-liquid cells are, however, more troublesome, and may be set aside in favour of single liquid ones for many short experiments.

Bichromate Cells.

Fig. 2 shows, in principle, the way in which three or more of the bichromate of potash cells are made up. They are composed of two carbon

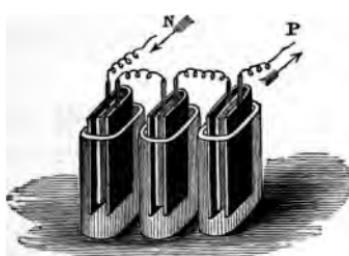


Fig. 2.—Simple Voltaic Cells.

plates, having between them a zinc plate, amalgamated as usual. The plates are contained by a glass or earthenware pot of the shape shown, and a dozen or two of such cells,

about six inches high, form a very powerful and useful battery in short experiments. This engraving was, however, only prepared to illustrate the make-up of single cells, and how they are joined together.

Whenever two plates are used in a single cell, and are held by a brass clamp, such as that shown in the illustration of binding-screws, they must be separated from contact with each other by having

placed between their upper edges a strip of wood, pasteboard, or other non-conducting material. The three cells here shown form a battery of three cells joined in series, that is, zinc to carbon and zinc to carbon throughout. The two carbon plates are connected together by a strip of copper, and therefore one wire from any one of them takes off all the current. Both sides of the zinc give off electricity, which passes through the *liquid* to the carbon plates, and so by the negative plate wire, as shown by the arrow and marked P. Thus the negative plate wire is the positive wire or pole, while the zinc plate wire, being the receiving or returning end of the battery, is called the negative wire or pole, as shown by N, and the arrow indicating the flow of the current.

Two wires thus come from a coupled-up battery of cells, and scarcely any action commences within the battery until the ends of these conductors are brought together in metallic contact, or until some conducting circuit, such as through an electric lamp, is provided for the electricity to flow from and back to the battery.

For electric light purposes it is always best, up to 50 cells, to join up in series—zinc, carbon, zinc, carbon; but this will be further spoken of in connection with Bunsen's cell.

A plate of zinc between two plates of carbon then forms a single cell. A brass clamp may hold the whole together, the zinc being prevented from contact with the carbon by strips of wood as thin

as possible, while the two carbons are joined as one by the brass clamp. Elements, or sets thus made up, can be charged with dilute sulphuric acid only, and for bell-ringing or telegraphy with a solution of sal-ammoniac, but for electric light purposes, requiring a powerful current, the containing pot should be three-fourths filled with a mixture as follows :

Crystals of bichromate of potash	3 oz.
Warm water	1 pint.
And (when cool) sulphuric acid	2 oz.

When this liquid is fresh, it causes the pairs immersed in it to give off a great deal of electricity—that is, a strong current. The potash salt is in reddish crystals, and costs about 1s. per lb.

Pairs of bichromate of potash cell plates should not be immersed in the solution until the current

is really required and all is ready. Of course, all the pairs, joined up by spirals of wire, may lie near the cells until the time comes for placing them in the liquid; but a far better plan, and a most convenient and cheap containing cell, is



Fig. 3.—Battery Cells.

shown in Fig. 3. Bottles of this shape, and to hold about a quart, are easily procurable; the size

of neck is sufficient to admit the pairs of plates, while the liquid is not readily splashed over the top. On the cell to the right is shown a stout brass collar, A, soldered around the neck tightly. To this is soldered securely an upright stout brass wire, bent as shown at B. The object is, of course, to provide a convenient hook upon which to hang the pairs of plates when out of the liquid. All the cells should have this arrangement, and may be put out of action in a moment by pulling up and hooking the plates by their wire or in a loop soldered on the clamp.

Fig. 4 exhibits a more expensive and elaborate form of the bichromate of potash cell. It is very handy for experiments, requiring little attention after the liquid is put in. The pair of carbon plates reach from the wooden or ebonite cover of the bottle to the bottom, and remain permanently in the liquid. This does the carbon no harm. The liquid will *keep* any length of time, but the time it will *work* is, of course, limited to perhaps 15 minutes, if the bulk be small. The zinc plate is attached to a sliding rod, movable in a split brass tube fastened to the cover, and may thus be lifted clear of the liquid as soon as the current is not wanted. This saves the zinc and the solution.



Fig. 4.—Small Bichromate Cell.

The carbon plates are made fast by screwing or riveting to stout angular pieces of copper, and these coming together, and having soldered to them the tang of a binding-post, one wire serves as before for both plates. The split tube is connected by a strip of copper or brass to the other binding-screw. The ebonite cover—or a wooden cover will do equally well—has a brass collar to fit over the neck of the bottle.



Fig. 5.—Bichromate Cells.

Fig. 5 shows another shape of bottle, of larger size, and also exhibits the connecting up arrangement in such cells. The zinc should be as large as possible, and its top should hold a piece of ebonite cut to fit between the carbon plates, to prevent the

zinc from twisting and closing the circuit within the cell.

The amateur may make such cells himself, as they usually cost as much as 8s. for pint size, when bought. For electric light purposes, however, if the operations go above 8 or 10 cells, the first hook arrangement will be found much more economical and even better in use, because the zinc plate may be much larger.

The art of working bichromate cells consists, first, in never leaving or placing the zinc in the solution when the current is not needed, pulling it out the instant the experiment is performed, and not leaving it in the liquid for over five minutes without either disturbing the cell or moving the plate. The great defect of such cells is the want of circulation in the liquid, so that, when the liquid is quite still, the current is soon weakened. If heat can be applied, so as to give some circulation, the current will come off almost in full even flow until the solution is exhausted. Exhausted solutions may be thrown away, or they may be spontaneously evaporated, when the chrome alum formed in the action may be recovered. This salt is of value in dyeing.

All the connecting wires should be of cotton-covered wire, at least as stout as No. 16 Birmingham wire gauge. All connections must be clean and metallic; electricity will not pass through dirt, coatings of oxide, or cotton covering. Connecting points in clamps should be occasionally looked to,

to prevent bad contact. Bad connections will often utterly weaken the current, and sometimes stop it altogether. To give some convenient elasticity, the connecting wires may be wound on a rod to make a spiral; but too much wire must not in this way be introduced into the circuit, or the current will be weakened by its resistance. All connections to lamp or instruments should be strong, or No. 12 copper wire. All uninsulated wires must, of course, be kept from contact together, otherwise the circuit may be closed outside the battery before it reaches the electric lamp or other instrument.

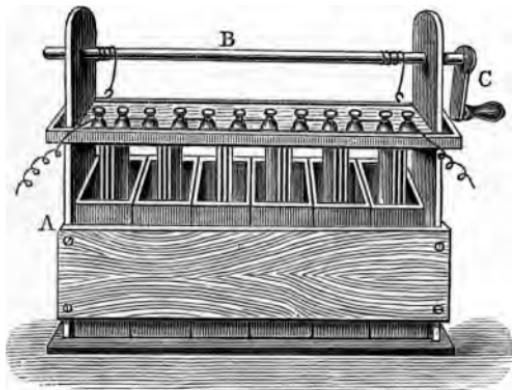


Fig. 6.—Six-cell Lifting Battery.

Fig. 6 is a form of bichromate battery in much favour, as it admits of a great number of plates being placed in and withdrawn from the liquid at once. The arrangement also allows of the easy agitation of the liquid. The author has seen a

battery of this kind of 25 quart cells give a beautiful electric light for a considerable time by an ingenious arrangement of a weight, wheel, and lever rocked by a crank applied to the lifting-crank. In this way the plates were lifted a little way, and then dropped every second, thus agitating the liquid—the result being a steady current.

A is a wooden frame, holding as many oblong glazed pots as may be required. The plates are all attached to a wooden holder above them as shown, above which come the binding-posts as in other forms of the cell. This holder is capable of sliding up and down upon A, by means of the handle and spindle with cords, B and C.

Number of Bichromate Cells required.—This will all depend upon the light required. A light will be given by 6 cells of quart size, but it will be a small light, and will not permit any actual separation of the carbon points; 12 cells will give much more than double the light, and 24 will admit of actual separation, giving the true voltaic arc and a very brilliant light; 50 cells will give rise to a voltaic arc of great splendour, probably equal to 1,500 candles.

It may be said that, up to 50 cells of the quart size, it is generally advantageous to join up in series with ordinary lamps.

The electromotive force of 50 cells is usually sufficient, and any cells over should be connected in parallel circuit to an equal consecutive number of cells of the 50 elements, so as to reduce the

internal resistance of the battery whilst maintaining a sufficient electromotive force. Thus, if there are 100 cells, each 50 should be joined up in series, and then the negative wires from both should lead to one screw of the lamp, and both positives to the other screw. Thus the electromotive force of the battery is not increased, but the resistance of the elements that are doubled is halved. But of course the most advantageous mode of grouping a given number of elements must depend on the resistance of the external part of the circuit; for with a given number of elements they should be so joined that their internal resistance shall equal the external resistance. It will be unwise to expect over half-an-hour's continuous light from any bichromate of potash battery; and there must be agitation of the liquid to get even this amount of light. The solution may be refreshed afterwards by the addition of other 2 oz. of sulphuric acid to the pint; but acid further than this will do no good.

Constant Lights.—Bunsen's Battery.

The original battery invented by Bunsen really consisted of a cylinder of carbon for the negative, and the zinc, in the form of a cylinder also, was put inside the porous cell. This form is expensive to make, and also more expensive to use than that now known as the Bunsen cell.

Fig. 7 is a view of a Bunsen cell of approved construction. The outer pot in the view is of glass,

to make the interior more clear. The positive element consists of a cylinder of thick sheet zinc, to fit easily into the outer pot. A is a projection left upon the zinc while cutting it to size; it serves to give a fastening to the binding-screw clear of

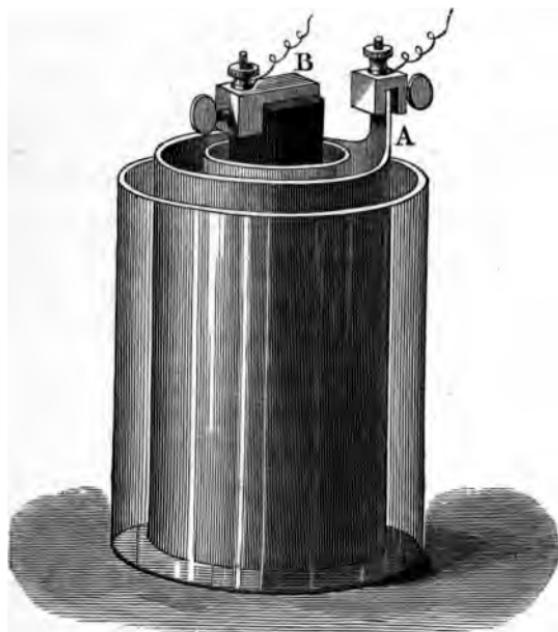


Fig. 7.—Bunsen Cell.

the liquid. The screws are of brass. Inside the zinc cylinder is a pot of porous earthenware, as before indicated, and into the porous pot, completing the cell, is put a cylindrical or square block of gas carbon, with a binding-clamp, B, fastened to it.

It may be as well to preface further remarks upon this generator with the assurance that, with one exception, it is the only real producer of voltaic currents that can be cheaply applied and depended upon in the production of electric light. Its current, once started, is almost perfectly constant for about 4 hours, and a good light may, with confidence, be depended upon for 3 hours and over.

The roll of zinc, A, should not be a *complete* cylinder. The edges should not come quite together; a division, however narrow, should be left while bending. Both inside and outside of the cylinder should, and indeed must, be amalgamated, as is done with flat plates, and care is necessary to renew the amalgamation as soon as black patches are seen.

As to the actual making up of Bunsen generators, as here shown, the outer pots should hold nearly a quart of liquid at least. They are best made of brown well-glazed earthenware, as before recommended. The zinc cylinders should be cut to the size in the flat sheet, leaving the "tang" for the screw upon them for good connection, and then bent over a wooden former while hot. The porous pots should be higher than the zinc, and this should be higher than the outer cell. A soft porous pot is best, of white or red materials. Inside the porous cell is placed the carbon block, which should be highest of all, and may be either round or square; but square blocks are almost always in use, and are easily procurable at about $\frac{3}{4}$ d. per inch in height,

retail. A hard, clear grey carbon should be chosen, and black and porous varieties rejected, because they add to the resistance of the circuit and reduce the force otherwise.

It is a common practice simply to clamp the carbon by a binding-clamp of brass for the connection. This is, however, when the cell is to be used much, a bad and decidedly troublesome way of getting contact. It is by far better to give the block a heading of lead. To do this, dry the head, cut a notch or two around it $\frac{1}{4}$ in. from the end. Melt the lead and pour it into some square holder, such as a cavity made in hard putty or plaster of Paris. Before the lead sets, dip in the carbon end, and allow the whole to solidify before removal. While still hot, the binding-screw may be soldered on, and before it cools the whole should receive a good coating of melted pitch; or, what is much better, dip the head in melted (solid) paraffin, which, when cool, will effectually defend the connection from outside attacks of the acid.

A better way still, although not so quickly accomplished, is to electrolyte a heading of copper upon the rods, to insure the best possible connection. To do this, partly fill a porous pot with acidulated water, place this in an outer cell containing crystals of copper sulphate dissolved in warm water. Heat the rods, and give them a coating of paraffin, driven in with a hot iron, between where the liquid will reach up to and where the heading will reach down to. If any paraffin goes upon the

end, drive it back by heating; cut now a few notches in the head as before, and drill a hole right through, in which place tightly a piece of stout copper wire, having $\frac{1}{4}$ in. of the end projecting at each side. Tie to this a wire, at the end of which fasten a strip of zinc, which place in the porous cell, while the carbon head dips into the copper solution. As soon as this is done, a deposit of copper will begin to form upon the wire and carbon, and when it has attained a thickness of good brown paper, remove, drill two holes right through the copper and carbon, soak a little time in warm water, dry off, and place for some time in melted paraffin to obtain an efficient protection. The binding-screw may be soldered to the copper, which will be found of the greatest value as a heading that cannot give trouble.

The exciting solutions or liquids are:—

In the outer cell, with the zinc . . . 1 part sulphuric acid; water, 4.
In the porous cell, with the carbon . . . strong nitric acid only.

This "charge" will work the cell for about 4 hours. After this the outer acid will have exhausted itself; but the nitric acid, which will have turned from a clear liquid to a reddish colour, may be used again. The second time of using will turn it green, and the third time quite clear again, when it should be thrown away and replaced by fresh. It is no economy to use nitric acid of inferior quality; it should be concentrated, and will cost, when good, about 10d. per lb. retail.

The Bunsen, while at work, gives off the fumes

of the nitric acid, which renders it necessary that it should be placed out of doors, or in a place where there is a draught of air. These fumes are injurious to breathe; they are worst while the porous cells are being emptied into the nitric acid stock bottle, but may be quite avoided in the open air.

In the working of large batteries of the Bunsen cell, some special arrangements are required to enable the attendant to get through the work of charging quickly and accurately. First, then, the sulphuric acid mixture must be prepared in a large bottle beforehand, by pouring the acid into the water — *not the reverse* — and stirring. It is most convenient to have a graduated measure, by means of which the correct quantity of nitric acid may be determined before placing in the cell. This is of more importance than might at first seem to be necessary, but a measure that can be quickly and easily filled to a known point, and as speedily emptied into the cells, will not only be cleanly, but will prevent spilling the nitric acid into the zinc compartment, an accident which sets up violent local action upon the zinc. It will first be necessary to find how much liquid will fill the porous pots to within one inch of the top when the carbons are in them, and then to fill all the cells with the carbons and zincs near at hand. It is further of consequence to have the liquid within the porous cell at the same height as that in the outer pot.

This filling up should not be done until near the time when the light is wanted; a dish of water

should be at hand in the case of accident by burning the hands with nitric acid, and it is well to have in use the oldest clothes, because nitric acid will, if dropped upon them, destroy the part. Quickly place the zincks and carbons in their respective cells first, and then go backwards over the series, making the connections with certainty. See that each screw is well home, and that there is no bad connection throughout. As to the time such operations occupy, a battery of 50 Bunsens may be unpacked, acid mixed, and the light produced within twenty minutes.

Again, in pulling the battery to pieces after operations, all the connections should first be loosened; then the zincks should be placed one by one in a bucket of water to wash off the acid. The carbons are next similarly treated, and after putting a funnel in the neck of the nitric acid bottle, the porous pots should be emptied one by one, and then plunged in water. The outer liquid may be thrown away, as it is useless, or nearly so. Porous pots should, after once being used, be kept in water for a few hours to soak out any nitric acid or zinc sulphate, which while dry would crack them. All connections should be well washed and dried, and before again using should be looked to for dirt or bad contact points, which must be scraped bright or filed.

Zinc cylinders showing black patches should be again amalgamated, but this will probably be unnecessary until after the third time of using.

The force of the Bunsen will increase after setting up for about an hour, and the full effect will not be attained until the acid soaks through the porous pot. Carbons, as in bichromate batteries, are not affected in the least, and will last any length of time. The zinc is consumed slowly, through the mercury coating.



Fig. 8.—Bunsen Cells.

Twenty-five cells of the Bunsen will give a very brilliant light, and 50 will produce an arc of great power, while 100 will, when coupled in two parallel circuits of 50 each, so as to give an electromotive force of 50 and a resistance of only 25, produce effects of the most splendid character. The conducting wires must be stout—about No. 12, and even stouter conductors should be employed when 100 cells are used, joined up in parallel circuits of 50 each.

Fig. 8 shows three of the Bunsen generators of the cheap kind, in glass pots, and connected properly in series. The zinc cylinders have straps of copper riveted to them, and the carbon connections are brass clamps, with screws on the top for holding the ends of the straps, which, for this kind of clamp connector, should be slotted out.



Fig. 9.—Battery Carbon.

Fig. 9 shows the carbon rod, with another kind of binding-screw soldered to a neater brass heading.

Copper straps are, however, the best connection in a battery of any size, because small wires get hot and offer great resistance to the passage of the current. It is wise to solder as well as rivet the straps of the zincs.

Fig. 10 is a view of a pair of superiorly finished

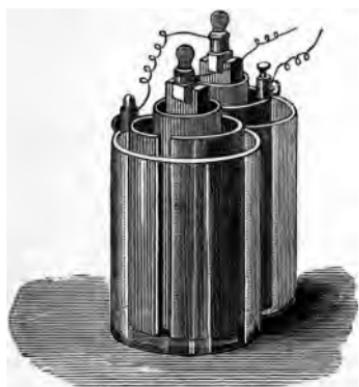


Fig. 10.—Pair of Bunsen Cells, showing connections.

cylinder. This separation is chiefly for the purpose

Bunsen cells, for laboratory use. They are fitted with removable screws upon both the carbons and zincs. The containing pots are of glass. This engraving exhibits the separation which should be made between the edges of the zinc

of preventing the formation of local currents in the zinc, while it also assists the outer liquid to more freely circulate.

Various arrangements of the Bunsen cells may be adopted in making up a handy battery. The framework and lifting arrangement spoken of in connection with the bichromate cell is also applicable to the Bunsen. There is, however, one disadvantage in the two liquid cells, and it consists in the mixing tendency of the two liquids whether the cells are in action or not. It is thus almost impracticable to arrange a rackwork frame for the Bunsen, so as to obtain the convenience of the arrangement to the extent previously described in the bichromate. It is better, however, to have the means of lifting them out, as it is useful when the battery is put into action for short experiments extending to about one and a half hours. During this time no great mixture will have taken place, and the zincs and carbons, arranged on the lifting-board just above their respective pots, may be lowered as required. There are some advantages in the frame used in this way. Bunsen cells are also best put up in long boxes while in action.

Iron Cells.

With the primary idea of effecting economical working, a cell has been tried, the invention of Mr. Slater, and others. All that can be here said of it, as well as of every other form of cell in which iron is employed yet introduced, is that it

is entirely unfitted for use in inexperienced hands. It has many objections, but its chief one would appear to be the tendency of the acid in the iron compartment to boil over when least expected. Such cells are, moreover, false economy, as will be found on working them for electric light, although the first cost may be lower than that of the Bunsen.

Chromate of Lime Cells.

To replace the potash salt with greater economy and equal power in working, a cell of the double liquid kind has been devised which has proved to be about as constant as the Bunsen, while it is almost as effective in working, and is undoubtedly cheaper when properly made.

The chief point in the construction is to secure as large a negative surface as possible, and, by means of a soft porous cell, to reduce the internal resistance of the combination.

Several forms of make-up have been tried. The best is a cylinder of carbon surrounding a large porous cell holding the zinc as a cylinder. Carbon cylinders are difficult to make. The graphite must be ground finely, or that deposited as powder upon the retorts may be used direct. It must be mixed into a stiff dough with water and sugar syrup, then baked until hard, and, while still hot, plunged in a strong solution of sugar or tar, and finally heated to whiteness and cooled slowly.

A make-up of this cell devised and used by the

author is much more simple, and to all appearance as effective in use, while it is incomparably cheaper.

A large soft porous cell is taken, in which is placed centrally a thin rod of carbon, or a Bunsen rod, with a screw affixed. Around the rod is packed a quantity of broken carbon in lumps as large as hazel nuts. Over the top is run melted pitch, and a conical hole is left for the introduction of the liquid. The outer pot, as in the Bunsen, contains a cylinder of zinc, and its diameter should be only just enough to admit the porous pot freely: the object being to have the zinc near to the porous pot. In order to allow the outer liquid greater freedom of action, the zinc cylinder should have a separation of about $\frac{1}{2}$ in. It is also a good plan to bore several $\frac{1}{4}$ -in. holes in the zinc cylinder. The cell is thus a carbon and zinc one, like Bunsen's. The exciting solutions are, however:—

FOR POROUS CELL.

Chromate of lime	·	·	·	·	·	2	ounces.
Warm water	·	·	·	·	·	5	"
Sulphuric acid	·	·	·	·	·	5	"

FOR THE OUTER CELL.

Water	·	·	·	·	·	1	pint.
Sulphuric acid	·	·	·	·	·	3	ounces.

The action will be found to give off little or no fumes. The electro-motive force is slightly greater than that of the Bunsen; but the internal resistance is also greater.

This same cell is available for use with another

excitant, which will be found to work even with greater force, and give little or no fumes for the first two hours :—

FOR THE POROUS CELL.

Bichromate of potash	·	·	·	·	2	ounces.
Nitric acid	·	·	·	·	10	„
Sulphuric acid	·	·	·	·	2	„

In the outer cell the solution is the same as for the Bunsen. This will be found to work with greater power than the Bunsen, and the internal resistance is less, but the cost of working is increased about 25 per cent. After use the porous cells should be emptied of their contents, and kept in water until again wanted. The same solution may be used two or three times, and if there be any appearance of a poverty of potash salt, add more.

Various modifications of such cells may be used. As a rule it is best to provide a strongly acid mixture for the carbon compartment. Thus the cell I have spoken of, as its construction is virtually the same as the Bunsen, may be used with great advantage as a Bunsen, and it will give a greater current than the common forms, while the cost of construction is very little more.

Cells Too Weak.

Avoid attempting to produce the electric light with the following cells :—Daniell, Smee, Manganese, Sulphate of Lead, Sulphate of Mercury, Chloride of Silver, Marie Davy (mercury sulphate

cell), Copper-Zinc (simple), Minotto (modification of Daniell), Léclanché, Grenet, Highton, Clark's Mercury, Peroxide of Iron, Perchloride of Iron, Calland's, Spiral Cell, Meidenger (modification of Daniell), and, in short, all cells used for telegraphy or bell-ringing.

The Grove Cell.

This cell admits of a very large and powerful battery being placed in a very small compass. Grove's cell is like the Bunsen, except that platinum foil is employed instead of carbon. The solutions are the same—that is, strong nitric acid in the porous pot with the platinum foil, and acidulated water in the zinc cell. To get the greatest power, it is best made up in pots like the Bunsen.

Fig. 11 represents the zinc cylinder of a Grove cell.

Another make-up, adapted to the purposes of



Fig. 11.—Zinc Cylinder.



Fig. 12.—Grove's Cell.

lecturers and where great portability is necessary, is shown in Fig. 12, where A is the zinc plate, in a

flat outer cell, and B the platinum foil plate, in a flat porous pot.

Fig. 13 shows these pots more clearly. Porous pots of this kind are more expensive than round ones. They should be thin in the sides, but the ends and bottoms for strength may be stouter with advantage.

Fig. 14 shows how the zinc plate should be bent, so that it may embrace the porous cell closely.

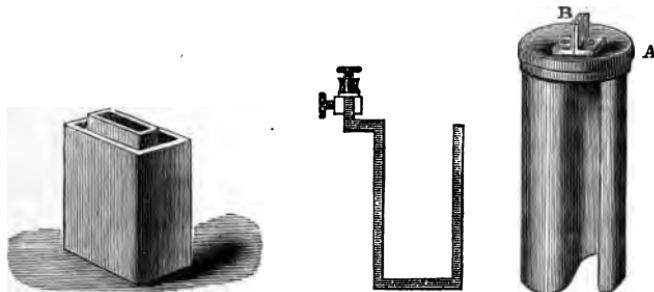


Fig. 13.—Pots for Grove's Cell.

Fig. 14.—Zinc for Grove's Cell.

Fig. 15.
Platinum Plate.

The generator has thus a great deal of zinc surface. To increase the otherwise somewhat small surface of the platinum plate, it should be corrugated, or simply very much wrinkled; but it is better to corrugate it in the direction of its length, which will both increase the effective surface and add to its stiffness. Fig. 15 shows the plate arranged for the cylindrical zinc of Fig. 11. A is a cover of wood or ebonite to which the plate is made fast, and a connecting strip leads to the binding-screw holder, B, which is of brass or copper sheet, bent at right angles, and secured to the wooden

cover by two screws. It is a mistake to purchase platinum foils too thin. There is no waste, but foil that is like tissue-paper is a constant trouble.

The chief objection to the use of platinum is its great cost, as it is not procurable as sheet or wire under £1 10s. per oz.; but an ounce of platinum will go a long way in foil of sufficient thickness for use in the Grove cell. The connection may be soldered on, but it is usually better to solder on a clamp-piece of sheet-copper first, across the top edge; and to protect this metal from the fumes of nitric acid, it should be coated, while warm, with Brunswick varnish, or sealing-wax dissolved in warm methylated spirit of wine. Any kind of clamps or screws may be used, but it is most convenient to have them removable.

Fig. 16 shows a ten-cell Grove battery, as used by lecturers for the production of small electric

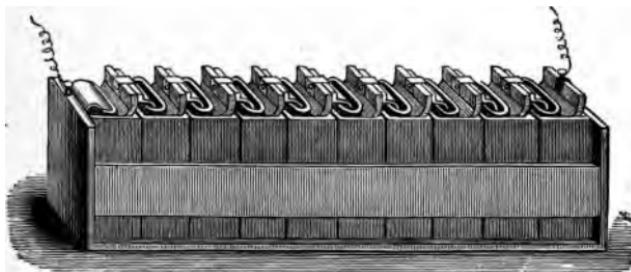


Fig. 16.—Ten-cell Grove's Battery.

lights. It is composed of the flat cells, and the foils are clamped by plain clamps to the zines throughout.

The resistance of Grove's battery is very small,

and on this account it will give, size for size, a stronger current than the Bunsen when the external resistance is small, although the difference does not warrant the extra expenditure except for travelling purposes, or when space is limited. A Grove's cell will cost about three times as much as a Bunsen. Twenty Grove's cells, or two cases of ten as the one shown, will give a good light, and five such cases of ten, coupled up in series, will produce effects of great grandeur.

It is of greater importance than with most other cells to have the conductors and connections used in Grove's batteries very stout and of good soft copper. The time it will remain in action is about the same as that given by the Bunsen. The Grove cells may be smaller than the Bunsen to produce the same effects. The same care is necessary in keeping the zinc amalgamated, and the bottom, or bend, is usually better rounded and well watched. Less nitric acid than is used in Bunsen's will be sufficient in the Grove pots. The author has used Bunsen cells made up in Grove pots with every success for operations extending over $2\frac{1}{2}$ hours. Plates of carbon must, of course, be used instead of blocks, and they should be as thin as may be convenient. This make-up is more expensive than that of the common shape of Bunsen. Grove porous pots should have a lip at one corner for convenience in pouring out the contents.

Battery for Photographer's Light.

It has long been known that the electric light is rich in actinic rays, and on this account it is of much value to the photographer in securing views of places and objects not reached by the light of the sun, or in the practice of portraiture.

It may be said that a good electric light will be found to work the rapid dry plates of to-day almost as easily as daylight at noon.

Since the introduction of cheap dynamo-electric machines, and the new gas-engines of Crossley and Otto, photographers in various cities have taken up the new light, and just now it is an easy matter to get a portrait taken at dead of night in more than one place in Regent Street and elsewhere. Very few photographers, however, can afford to go to the necessary outlay of about £110 for a gas-engine and machine with lamp.

The author has devised, in a modification of Dr. Byrne's negative plate cells, a voltaic generator free from most of the objections generally urged against the application of batteries. It is at first inexpensive, is easily managed and certain in results, and its maintenance low enough in cost to warrant its extensive use. It is, further, very portable, and may be made use of in travelling to secure photographs of caves and such places. It is not procurable commercially, and the intending user is therefore recommended to make it for himself, for

which purpose full instructions are given, with an illustration of the apparatus.

Assuming that the reader, from glancing at previous pages, is sufficiently acquainted with the usual make-up of a voltaic cell to understand readily minor details not here mentioned, it will be best to premise further remarks with an explanation of the nature of this new generator. It is, then, a simple bichromate of potash cell, with negative plates of a peculiar construction, and so arranged that a very powerful current may be obtained from even 6 cells by the aid of much agitation by air.

Each negative plate consists of a plate of copper, to one surface of which, as well as to its edges, a sheet of platinum foil, compact and free from pin-holes, is soldered, and to the opposite surface or back, a sheet of lead—the three metals being so united that the copper shall be effectually protected from the action of acids. The lead back and edges are then coated with asphaltum varnish, acid-proof cement, or any other like substance; and lastly, the platinum face, being first rubbed over gently with emery cloth, is to be thoroughly platinised.

To Platinise.—Fill a containing pot and a porous cell with acidulated water, and place the porous cell within the large pot. Tie a strip of zinc by a clean wire to the plate to be platinised; dip the zinc in the porous cell, and the plate in the outer cell, and drop into the outer cell, while stirring, a solution of platinic chloride in water. Add drop

by drop, with agitation, until the platinum surface is seen to turn dark, and to have acquired a granular deposit of platinum. Upon this surface depends to a great degree the power of the generator. If any difficulty is experienced in securing a good deposit, dip only a little of the zinc in the solution at first, and increase as the coating is seen to form. Dry carefully, and do not scratch the plate or remove the deposit, which it is not difficult to do before it is dry.

Each cell contains two such plates, between which a single zinc is suspended, and when the elements are immersed so that the exciting fluid reaches to within an inch of the top, a large negative surface is brought into action.

It will thus be seen that the platinum alone is the negative, or receiving metal, and the copper core a conducting body merely; while the lead, being almost passive, serves no other purpose than to protect the copper, so that any other, and, best of all, a non-metallic substance capable of resisting the action of bichromate solutions, might, with advantage, be substituted for the lead. The exciting solution to use in this cell is prepared as follows:—

Bichromate of potash	2 ounces.
Warm water	1 pint.
And, when cool, sulphuric acid	4 ounces.

Chromate of lime will give even a higher electro-motive force.

Fig. 17 represents a six-cell generator of this

kind. The cells are the ordinary brown glazed earthenware oblong ones used for the Grove and

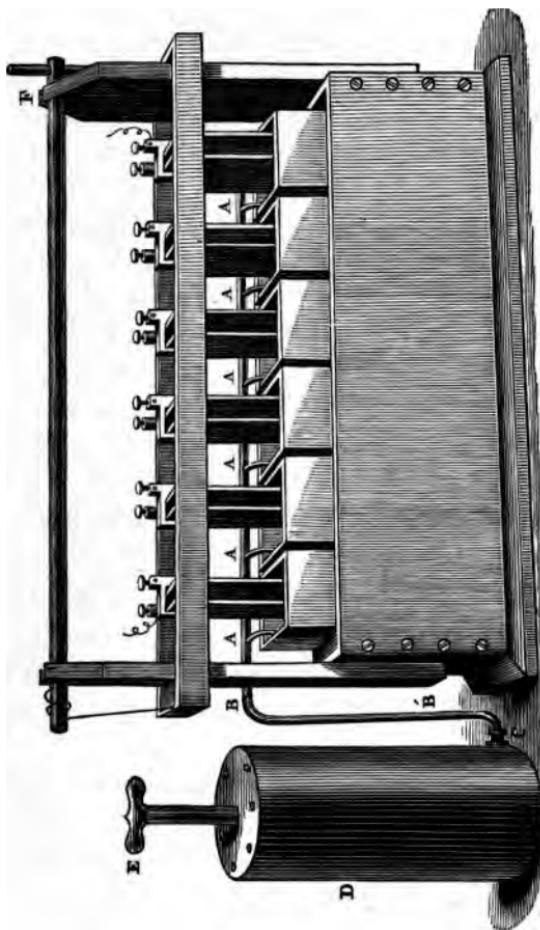


Fig. 17.—Bichromate Pneumatic Battery.

other batteries. They should be capable of holding at least a pint, and quart cells will be found more economical. There are three plates in each cell,

two platinised plates, and one amalgamated zinc between them. They are separated at their top edges by slips of wood or ebonite, against which they are securely clamped by stout brass clamps as shown. Thus the brass clamp, being in metallic contact with the lead, with clean scraped surface, represents them both as the positive pole. To the zinc plate in the centre is soldered a common binding-screw. Very stout and soft copper wires—about No. 12—must be used to connect up the elements in series zinc to platinum, zinc to platinum, and so on, with clean contacts. The sets of plates are fastened to a framing of wood, made to slide up and down the side uprights by means of an overhead shaft, cords, and handle F. This allows of the plates being drawn out of the solution the instant they are out of action to save zinc and solution, as previously described for common bichromate batteries. A ratchet wheel should be put upon the spindle, with adjustable pawl, to hold the plates in position when drawn up. For quart cells the plates may be 8 in. long by $4\frac{1}{2}$ wide.

Now for the air-distributing arrangements of this apparatus. A A A is a piece of inch lead piping, fastened to the back of the framework, from which lead, as shown, 6 smaller tubes ($\frac{1}{2}$ inch) of rubber or varnished lead. These extend to the bottom of the cells, and then run parallel with and directly under the plate edges. The ends are closed, and the horizontal portion is perforated with many

small holes. B B is a rubber pipe slipped over the end of A, its other end being made secure to the outlet, C, of a hand-pump D, worked by the handle E.

There must be a valve at C to close the passage to A when the handle is drawn up; otherwise the solution would be pumped out of the cells. The whole should be screwed to the floor, or have a projection upon which to place the foot for steadiness. It is better to use one of Fletcher's foot-blowers.

If these elements are lowered into the solution simply, it will be found that a much greater power is obtainable from them than that given by zinc-carbon batteries, previously mentioned. The full effect, however, for which this valuable battery is remarkable can only be got by pumping in air by the small tubes. A great disturbance of the liquid results, and the current is so much augmented in power that even a 6-cell battery will give a light equal to that given by a 30-cell Bunsen or Grove.

The air disturbance has no effect upon the electro-motive force of the battery although the volume of current given off is enormously increased, and any other means of effecting the required agitation would probably answer the purpose equally well. The suggestion of Professor Adams as to the air effecting a free circulation in the fluid, by which the metallic surfaces are kept constantly clear, is undoubtedly the correct explanation. The wonderful

effects are in great part due to the low internal resistance of the cell, owing to the peculiar arrangement of negative plate, partly to the peculiar effect of a rapid flow of air upwards through the liquid, and partly to the production of heat. The action of the air flow is principally mechanical, but by hastening the combustion of the zinc it tends to generate heat, which in turn reduces the resistance. The mechanical action of the air is to remove from the neighbourhood of the negative plate the chrome alum which is formed there, and from the surfaces of the zinc plate the zinc sulphate, formed by its union with the sulphuric acid; and to bring a fresh supply of solution constantly to the surfaces.

With a battery of ten cells, a platinum wire, 32 in. long, of No. 14 gauge (0.089-in. in diameter), was gradually brought to a glowing red heat, which ebbed and flowed with the cessation or renewal of the air flow. A brilliant electric light is maintained between two carbon points, which similarly varies in intensity with the flow of air, so that it is important to pump the air in regularly; and when this can be done by a crank attached to a heavy fly-wheel, almost perfect regularity is secured. The effects which are ordinarily produced by 60 or 70 Grove or Bunsen cells were obtained from ten cells of this battery in the laboratory of Mr. Spottiswoode, F.R.S., at Sevenoaks.

To prevent the possibility of any disappointment in the use of this apparatus, it will be as well to tell

the reader at once that for every 15 minutes or so of electric light the cells will be nearly exhausted, and to continue at full power ought to be refilled. The light is, however, usually cheap enough for ordinary working.

CHAPTER III.

THERMO-ELECTRIC BATTERIES.

MUCH has been done, and much more remains to be accomplished in the generation of electricity for illuminating purposes by heat and combinations of metals.

A current of electricity is produced in a circuit composed of two different metals when their junction is heated. The metals which exhibit this property to the greatest degree are bismuth and

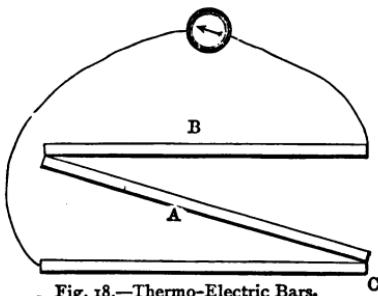


Fig. 18.—Thermo-Electric Bars.

antimony. If two bars of bismuth, B and C, and one of antimony, A, are placed as in Fig. 18, and heat applied at one junction while the other is cooled by radiation or otherwise, a current will flow into the wires and through the galvanometer.

The two most efficient thermo-electric piles in use up to 1876 were probably those of MM. Clamond and Nöe; great numbers of such pairs being employed to multiply the force and current.

By the expenditure of 21 lbs. of coke per hour, M. Clamond, of Paris, has succeeded in maintaining four electric lights, each having an illuminating power of 220-standard candles. This is vouched for by the Count du Moncel; and, indeed, there should be nothing impossible, or even difficult, in the accomplishment of such a result. Sixty couples will yield, when well constructed, a current equal to a gallon Bunsen cell, and less than 3,000 elements will give the effects of 50 Bunsens with an expenditure of 80 cubic feet of gas per hour. Such results are reported of the couples of M. C. A. Faure.

M. J. E. M. Sudre, who has been working in conjunction with M. Clamond, has taken out a patent for the following advances in the make-up of thermo-electric batteries.

1. For the construction and arrangement of thermo-electric chains composed of couples, the resistance of which has been reduced to a minimum.

2. The combination and arrangement of the chains with two metallic plates of which the opposing surfaces are coated with an insulating layer; which plates form part of two metallic systems, one serving to collect and communicate the heat, and the other to abstract and diffuse it.

3. The combination and arrangement for binding, coupling, and insulating the thermo-electric chains, when several are mounted side by side between the two plates.

4. The application and use of the collector and diffuser to any description of thermo-electric piles, so as to maintain the necessary difference of temperature between the extremities of the couples without lateral waste of heat.

One of the main features of the invention, as described, is the maintenance of the necessary difference of temperature between the two solderings of each couple by placing those couples between two surfaces from which they are electrically insulated. It is stated that in the construction of thermo-electric couples and chains, an isolated thermo-electric couple is ordinarily composed of a prism in metal or alloy casting and of a polar plate of iron, copper, German silver, or other suitable metal soldered to each of its extremities. The plates do not ordinarily interfere in the slightest with the electric force obtained, and it is the bar, such as that of antimony and zinc, which produces the effect.

When it is desired to use two metals or energetic alloys of which the effects are combined, and which are easily fusible, such as bismuth and antimony, the couple is then formed of two bars, which are joined together by a cross bar which binds them and is soldered to each of them.

The total resistance of a couple is composed,

1st, of the resistance of the connecting plate; 2nd, of the resistance of the bar, ordinarily composed of alloys sufficiently resistant, and 3rd, of a particular resistance at the points of contact or soldering between the plates and the bar. The metallic plates should be of a metal sufficiently conductive, such as copper, iron, German silver, &c., and should be sufficiently large and thick to present but a feeble resistance. They should also be as short as possible. These conditions, it is claimed, are realised in the improvements of M. Sudre. Again, the bar should have very little resistance under a small volume. The inventor takes as a datum the formula $R=k \frac{L}{S}$ in which k is a specific co-efficient for the metal employed, L the length of the bar, and S its section. As the resistance depends on the ratio $\frac{L}{S}$, the volume of the couple may be diminished by diminishing the length and sectional area in equal degrees, in which case the resistance will not be affected.

The length which should be given to the bar depends upon the difference of temperatures employed. For differences of temperature between 10° and 120° (Centigrade), M. Sudre gives to the couples a length of 10 or 12 millimètres, whilst if the higher temperature reaches 300° the length varies from 20 to 30 millimètres. The resistance at the points of contact or soldering is of the highest importance. The junction should be made so that

the plate is in contact with the whole section of the bar. The plate should penetrate to a very little depth within the bar, so as not to diminish too much the electro-motive force of the couple ; for the really effective difference of temperature is that of the two solderings, and this difference diminishes as the plates penetrate more deeply into the bar, and thus approach one another.

In constructing the couples M. Sudre cuts the extremities of the connecting plates in the form of a comb, the teeth of which are afterwards twisted so as to present a helicoidal surface, which holds the plates, as it were, screwed into the bars. The cut portion of the plates is so adjusted in a mould that the teeth become embedded in the bar when this is cast. A considerable number of bars are cast simultaneously, and constitute a thermo-electric chain. The external portion of the plates is coated with asbestos-paper, mica, terra-cotta, or other suitable insulating material, which may be cemented to the metallic surfaces by means of silicate of soda solution.

The chains are arranged in battery between two metal plates, which may be plane or curved. Each of the plates is kept cool on one of its surfaces by means of a thin layer of some bad conductor of heat. One of these plates constitutes the collector and the other the diffuser. In order to maintain the diffusing surface at a low temperature, M. Sudre employs a cooling-box of water, fed from a tank.

An important question remains yet to be solved as regards this pile, and that is the amount of maintenance and repairs required by it. Should these be of low cost, a generator very well suited to purposes of artificial illumination will result.

CHAPTER IV.

MAGNETO-ELECTRIC GENERATORS.

IN the year 1831 Professor Michael Faraday made one of those brilliant discoveries which have immortalised his name, and has formed the starting point of all those ingenious electro-mechanical engines of the present day for converting the energy stored in fuel into light. Arguing that as from electricity in the electro-magnet he obtained magnetism, so from magnetism there must be a means of obtaining electricity, he experimented with his usual skill and patient perseverance, and was rewarded by the discovery of what has been termed magneto-electricity. He found that if a magnet was moved near a coil of insulated wire forming a circuit, a current of electricity was induced in the circuit during the movement of the magnet.

Fig. 19 illustrates, in a simple way, the manner in which the generation of an electric current may be brought about by means of a magnet and coiled wire, with a galvanometer, or current measure, to prove its existence. A is a bobbin of insulated copper wire, having attached to its ends, or in

circuit, a common galvanometer, B. When a permanent steel bar magnet, C, is quickly passed into the coil by the central aperture, a current is caused to circulate in the wire, and its direction will be indicated by the direction in which the galvanometer needle moves. This current is, however, only momentary, that is, it lasts just as long as the magnet is in motion within the coil, and ceases as soon as the motion ceases. If, however, the magnet is now withdrawn, *another* current will be caused to circulate in the coil, and its direction will be opposite to that of the first. This will be shown by the needle of the galvanometer, B, being deflected to the left.

This simple experiment contains the first of all the laws of magneto-electric induction, and is, in fact, the base or principle of every dynamo-electric machine noticed in this work.

Were it possible or practicable to make the magnet move backwards and forwards within the coil rapidly by means of any mechanical contrivance, we should have a magneto-electric machine on a small scale. The currents would be alternating in direction, just like those from the machine now used to burn the "electric candles," and would be induced in the coil just as long as the motion was kept up. Again, were it possible to cause an endless magnet to move in one direction in the coil continuously, we should have a machine yielding a constant current of electricity in one direction only.

The necessary materials for the practical illustration of this important principle may consist of a 3-inch long paper bobbin, wound with five layers of No. 22 B. W. G. cotton- or silk-covered copper wire; a galvanometer, or current detector, composed of a magnetised sewing-needle, hung by its centre, by a thread, within an oblong coil (say ten turns) of the wire. The needle must, of course, be held parallel with the wire coil. A steel bar magnet of the common kind, and 8 inches long, will complete the apparatus practically as exhibited in Fig. 19.

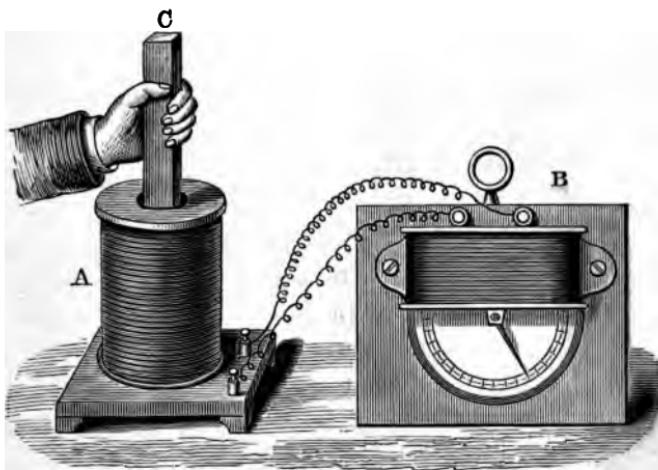


Fig. 19.—Faraday's Experiment.

This is called *magneto-electric induction*. It is more difficult to move the magnet in the coil when the circuit is closed than when it is open. The action that takes place may perhaps be explained as follows:—The movement of the magnet

induces a current in the coil, forming it into a magnet with its poles in a position such as to attract the poles of the moving magnet in the reverse direction to that they are moving in, and thus opposing the motion of the magnet. This opposition has to be overcome by force, and the energy thus expended, less that dissipated in heat, reappears in the form of current in the coil circuit. The magnetism thus forms a connecting link between the movement of the magnet and the current produced.

Fig. 20 illustrates an experiment in another kind of induction—*current* induction. Some electric

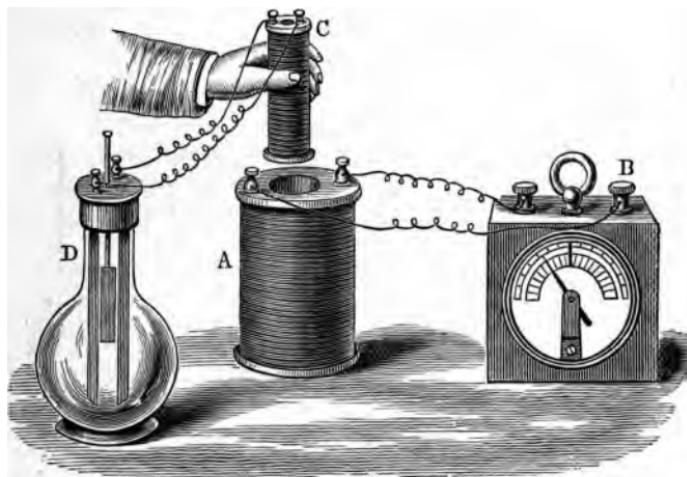


Fig. 20.—Induction Experiment.

generators have been constructed upon this principle; they are not the most successful, but it is important that the reader should understand, as

bearing upon the whole art of dynamo-electric machine construction, that a bobbin A, coiled with wire and connected to a current detector B, has induced in it currents in opposite directions as the wire bobbin C, drawing current from the voltaic cell D, is moved up and down in it. The principle is identical with that shown by the first experiment, the connecting link between the energy and the current produced being, in this case, not magnetism but electricity itself. All that can be done by the magnet may be done with the current bobbin C.

The materials to illustrate practically this second phase of the first law may consist of the same larger bobbin and galvanometer, with a ruler, coiled with two layers of No. 22 wire, connected to one of the bichromate of potash cells already mentioned.

First Magneto-Electric Machine.—A year after the publication of Faraday's experiment, a magneto-electric machine was brought out by Pixii, who caused the magnet to revolve its poles near to the iron cores of a pair of bobbins forming an electro-magnet. He, in fact, caused by mechanical means a permanent magnet to induce currents in the wire of an electro-magnet.

It comes to exactly the same end, whether the electro or permanent magnet is moved. Saxton, in 1833, improved the arrangement: he placed the whole apparatus horizontal, fixed the compound horse-shoe magnet, and rotated the armature in front.

E. M. Clarke, in 1836, designed the construction exhibited in Fig. 21. He placed the magnet vertically and revolved the coils about a horizontal

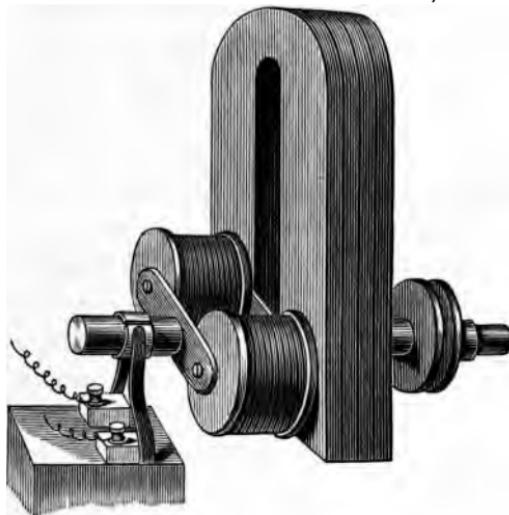


Fig. 21.—Clarke's Machine.

axis, and added a commutator to make the currents flow in one direction, which the author has endeavoured to make plain in Figs. 22, 23.

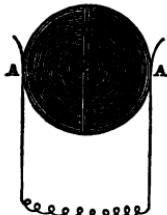


Fig. 22.—Commutator: End.

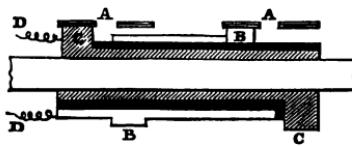


Fig. 23.—Commutator: Section.

In Fig. 22 are shown the two halves of a metallic cylinder, insulated from each other by some non-

conducting material as shown. A A are two contact springs for collecting the currents. Let us suppose that a constant current is being supplied to the two halves of the cylinder: in this case, as long as the cylinder remains in the position shown a direct current will pass to the springs, but if the cylinder is turned halfway round, the current will flow in the opposite direction in the springs, because the ends of the circuit connected to the cylinder remain the same, and communicate now with reverse springs. This is supposing a current in one direction, and as long as the cylinder rotates, the current will be reversed at each half-turn. The machine Fig. 21, however, gives alternating currents to the cylinder, and as these currents change direction just at the point where the commutator reverses, it is obvious that the alternating currents will now be made to flow in the springs always in one direction.

In practice, the common commutators are made like B and C, Fig. 24, which shows Stöhrer's machine of 1836. B is a cylinder, an explanation of the construction of which is given at Fig. 23, and C is a pair of contact forked springs. A and A in Fig. 23 represent the ends of the pair of springs C, just spoken of, and the cylinder is made up as shown in section. There are two metal tubes on the spindle, and they are insulated from each other by a tube of ebonite or wood, shown black. The metal tubes are connected to the wire coils as shown. B and C are projections on these tubes. They go half round the circle, B and C (bottom) on one side,

and B and C (top) on the other. At each half revolution, therefore, as the coil changes the direction of its current, so do the cylinder and springs, the result being a constant current in one direction.

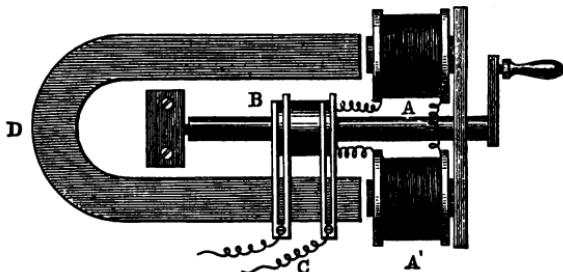


Fig. 24.—Stöhrer's Machine.

The current is strongest, of course, just as the coils, with their iron cores, pass the poles. In these machines, therefore, we have simply an electromagnet revolved before the poles of a permanent magnet.

Clarke's machines are usually employed for "shocking" or medical purposes, and as no shocks would be felt upon grasping handles fixed to the wire ends were the currents continuous, it is usual to arrange an interrupter in the circuit. This may be done either by employing a third spring, working on a brass tube split, so as to give a break of circuit, at its centre, or by making the half-rings in Fig. 23 overlap on the tube—that is, making them slightly pass the central line. The result will be that the current at each half-turn will pass for an instant by the fork of the spring, so cutting it for the same period of time from the outside circuit.

Concerning the practical construction of these machines, it is not the author's intention to dwell upon it at great length, on account of their simplicity, and because he has other, better, and newer information on constructing a useful machine to give. It will, however, be useful to state that the iron used in these revolving electro-magnets, as *cores* and *backs*, should be as soft and pure as possible, so that it may with rapidity change its magnetical polarity. Hard iron will develop only weak currents. The material usually employed is Swedish iron, made soft by soaking in a blood-red fire for some hours, and then cooling very slowly by burying in the hot ashes or allowing the fire to go out. The parts of iron to be screwed together must be quite clean, and in order to secure a good connection they should be quite flat.

The size and number of layers of *wire* must be regulated by the purpose for which the machine is intended. If high electro-motive force be required, as for a shocking machine, the wire should be fine, to give a great number of turns; but if the currents are required to do work in an external circuit of low resistance, a thick wire is to be employed. The electro-motive force and resistance of that part of the circuit formed by the moving coil will depend upon the number of turns of the wire, and upon its size. The greater the number of turns, the higher the electro-motive force, and the stouter the wire, the less the resistance.

The amount of current or quantity passing in a

given time in the circuit depends on the resistance of the whole circuit, as well as on the electro-motive force; and, therefore, if the portion of the circuit external to the machine is of small resistance the wire of the coils should be large, and if the external circuit is of great resistance the wire should be small and have many turns.

The principle is to some extent analogous to that of the voltaic battery, for when the cells are increased in size the internal resistance of the battery is decreased, and if the external resistance is small, the decrease in the total resistance of the circuit thus obtained more than counterbalances any decrease in electro-motive force. If the number of elements is increased the electro-motive force is increased, and if the external resistance is great compared to that of the battery, this more than counterbalances the increase of the battery resistance.

It is important that this should be borne in mind as bearing on the voltaic arc. Great electro-motive force will give a longer arc than a small electro-motive force; but if we get very small internal resistance we can produce with a given electro-motive force an arc which, though having a very small length, may, from the magnitude of the current passing, have a greater volume of light than with the greater length of arc. The exact relation, however, between all these elements of the question are not as yet entirely understood. Despretz, in a paper communicated to the French Academy

published in the *Comptes Rendus* of 1850, describes some experiments on the subject. He found that the length of arc increased more rapidly than the number of elements in series, and that by coupling given groups of batteries in parallel circuits (or as it sometimes is termed for quantity) very small arcs as regards length were obtained, but the amount of light given is not stated.

For medical machines, from No. 18 to 32 wire, cotton or silk-covered, will answer, according to the tension required. No. 22 or 24 will usually be found suitable, and as many as from five to ten layers may be wound on the reels. All connections must be soldered to prevent bad contact, and care is necessary that the wire passes from one reel to the other like the letter S (A, Fig. 25),

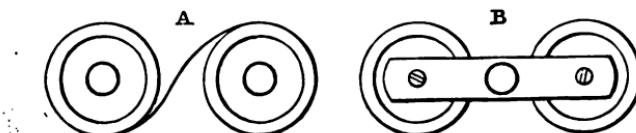


Fig. 25.—Electro-Magnet.

so that, in appearance, the winding may be in opposite directions. B, Fig. 25, exhibits the iron back and the coils.

Magnets of the permanent kind for such machines must be of good steel only. It is, indeed, imperative that the steel should be of the finest kind if the best effects are sought, and if it is required that the magnet should retain its force for many years. Steel of indifferent quality will soon become weak in magnetism.

The soft steel should be heated to a dull red, and then bent into the horse-shoe shape required. It should then be finished up, and again heated to a blood-red and plunged, bend first, in cold water. This should make it so hard that a file will not act upon it, when it is ready for magnetisation. This may either be done by a permanent or electro-magnet larger than the new one, or by a few cells of the strong batteries, such as the bichromate or Bunsen. In magnetising by battery, the legs must be coiled with insulated wire. Four layers of No. 16 will be sufficient on each, and one minute of passing the current will suffice. The circuit should be broken two or three times during the operation. The process of magnetising by a magnet is by rubbing it upon the steel, pole following pole, from end to end, in one direction. A piece of soft iron must cross the poles of such magnets when not in use or being magnetised.

Large Magneto-Electric Machines.

Some eighteen years passed without any great advance being made in the use of magneto machines, or any increase in their size, although several patents were taken out, some of which we shall have to allude to farther on.

The "Alliance" Machine.

In 1850 Professor Nollet, of the Military School of Brussels, commenced the design of a powerful magneto-electric machine, with the view of decomposing water and procuring oxygen and hydrogen

for the lime light. In 1853 a company for this purpose was formed in Paris called the Société Générale de l'Electricité, and a large machine by Nollet was experimented on in Paris. The experiments failed as regards the lime light, but experiments on the electric light made by Mr. F. H. Holmes with this machine, altered to a continuous current machine by means of a commutator, were so far successful as to lead to further experiments both in France and England. About 1859 the Compagnie de l'Alliance was formed for the manufacture of electric light machines. In the machines made by this company the commutator of Holmes was removed and the alternate current again adopted, and the machine was known as the "Alliance Machine," Fig. 26. Mr. Van Malderon had much to do with the success of these machines, which were used afterwards in the French lighthouses. From what was known when this machine was invented it was not possible, perhaps, to produce a better magneto-electric generator.

To a central shaft is made fast a series of copper or bronze discs, carrying each at its outer edges as many as 16 coils of wire with iron cores. The whole of this system, which may consist of as many discs as may be required, is caused to revolve by attaching the central shaft to a steam-engine. To an outside frame is secured a number of compound steel magnets: 8 sets of magnets are provided, and the coils revolve between each pair of magnet poles. The actual construction has been

varied many times; and not only for this reason, but because the author does not consider the matter of sufficient importance on account of recent advances, no detailed account will be given.

The currents given off are collected, one sign from the axis and the other from a brass ring upon, and insulated from, the axis. Alternate impulses are of course produced, and as there are as many

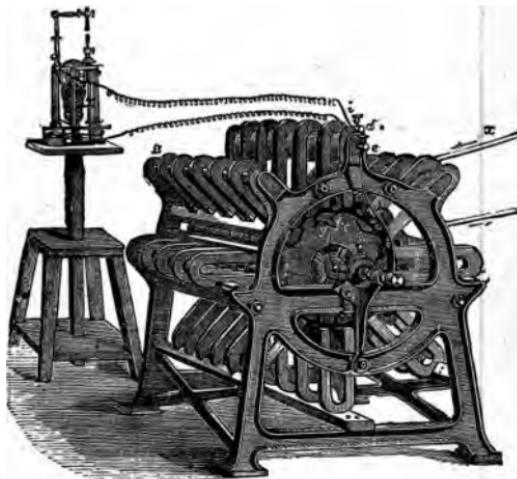


Fig. 26.—The Alliance Magneto-Electric Machine.

changes of direction as coils, the machine gives 16 alternate currents per minute; the shaft being driven at 400 revolutions, there must be at least 6,000 to 7,000 alternate impulses and changes of direction per minute.

As a matter of course, the parts, on account of these rapid magnetic reversals, become heated, but the way in which the parts are arranged causes

them to act as a wind fan, which not only does away with much power, but keeps the machine cool enough for continuous working.

It was a modification of this class of machine which first illuminated the south lighthouse at Cape La Hève, in 1863, and the same apparatus, slightly improved, was put down at the north lighthouse in 1865. Two 8 horse-power steam-engines drive a pair of the machines at each lighthouse. The light from one is equivalent to 1,900 candles. The same machine is fixed at Cape Gris-nez.

The Holmes Permanent Magnet Machines.

Mr. Holmes gave further attention to the subject, and in 1857 a large machine, made under his superintendence for the Trinity Board, was experimented on at Blackwall under the direction of Professor Faraday. In this machine the magnets, 36 in number, mounted on six wheels, rotated, and the coils were fixed and arranged in 5 rings of 24 each. Direct currents were produced by means of a commutator.

The experiments were satisfactory, and two larger machines were made for the South Foreland lighthouse. In these machines the magnets were fixed and the coils rotated as in the earlier Alliance machine. The machine contained 60 compound horse-shoe magnets mounted radially in their vertical planes, the poles of the magnets being turned away from the centre. The coils, 160 in number, were mounted on two wheels about 9 feet

diameter, 80 to each wheel. By means of a commutator direct currents were obtained. The power absorbed was $2\frac{3}{4}$ horse-power to each machine. On the 8th of December, 1858, the electric light produced from permanent magnets was shown on the sea for the first time at the South Foreland high lighthouse. These machines were afterwards removed from the South Foreland lighthouse and placed in Dungeness lighthouse, where the light was exhibited in February, 1862. Another machine was made by Holmes in 1867, afterwards used at Soutar Point lighthouse in 1871, in which the magnets were fixed but turned with their poles towards the centre. There were in this machine 7 rings of 8 magnets each, and between the rings of magnets revolved 6 wheels on the shaft, having 16 coils each. This machine had no commutator, and the alternate currents were taken off by brushes. It is, in fact, nearly a return to the Alliance machine, viz. permanent magnets, horse-shoe magnets turned with their poles towards the shaft, the coils revolving, and no commutator. Professor Holmes afterwards designed other machines which do not belong to the permanent magnet class, and will be described farther on.

The Siemens' Armature.

In 1856 Mr. C. W. Siemens patented an armature of great merit for magneto-electric machines, and which has been, and is still, extensively used in magneto machines of various descriptions. It consists

of a long iron bar, deeply grooved on two opposite sides, lengthwise. In this deep channel the wire is wound lengthwise of the bar, over its ends and along its sides. One end of the wire is soldered to the iron armature itself, and the other to a metal ring (insulated) on the driving spindle. This arrangement occupies the place of the electro-magnet in Clarke's machine, and it is rotated, by suitable means, *between* the poles of a strong magnet.

Fig. 27, which will further explain this, shows a cross section of the armature, with the wire in position. The sides of the armature are solid and rounded. Two cheeks, hollowed out, are shown attached to the poles of the magnet. These embrace the armature, which revolves very closely to them. It is usual in practice to wind the wire until it nearly completes the circular form of the sides. Rings of brass are then put over all, to prevent the wire from being forced out of position by the force of rotation. The pole cheeks are long, to embrace a considerable length of armature. There is very little churning of the air, as in Clarke's machines. This form of Siemens' armature has been employed by Mr. Siemens in a magneto-electric machine, with a number of magnets arranged parallel to one another, and by several other makers, among whom may be mentioned Mr. Wilde, of Manchester, and Mr. Ladd, of London.

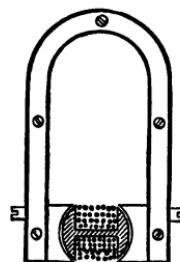


Fig. 27.—Siemens' Armature.

The armature, and several modifications of it, have been employed in magneto-electric telegraphic machines, and in the better class of medical apparatus. These forms of the machine do not, however, concern us here, although they are, historically, of much interest.

Breguet's Machine.

M. Breguet, a well-known manufacturer of electrical apparatus in Paris, constructs a machine which is composed of a pair of large permanent steel magnets, passing between the poles of which is a shaft carrying a stout iron disc, upon the face of which is secured, at right angles to it, a series of iron cores wound with wire. These cores are so arranged that both magnets act upon them, one magnet upon their free ends, and the other upon the ends fixed to the iron disc.

The apparatus is simply an extension of Clarke's principle, but the number of bobbins admits of a continuous current being given off. The coils are joined up as a battery in series. As the system is caused to revolve, all the bobbins on one side of the poles will give off direct currents, while those on the opposite side will give off inverse currents. These currents are properly collected by a pair of springs at the changing or neutral line. The contact slips are disposed readily from the central parts of the disc, and to each strip are joined the two adjacent ends of each pair of coils.

There is no actual break of circuit during the

revolution, because the contact springs are always bearing upon two or more of the radial slips.

On a large scale the machine would doubtlessly work very well, and is adapted for the rapid dissipation of heat generated by the magnetic reversals. But the same advantage is again a disadvantage, because the coils, being some way from the axis, act as a fan, and so consume power in churning the air.

C. F. Varley's Machines.

In the machines constructed upon the designs of Mr. C. F. Varley, actual, or nearly actual, contact is maintained between the armatures and the poles of the inducing magnets. The magnets themselves, together with the intermediate cores, surrounded by coils of wire, form a complete ring, link, or circuit of iron, or iron and steel. These permanent or inducing electro-magnets have their respective north and south poles continuously or nearly continuously closed, notwithstanding the movement of the armature or armatures; but the armatures, when rotated or moved to and fro along the iron or link, affect the direction of the currents.

In arranging a machine on these principles in the simplest and most elementary form, two horse-shoe magnets are placed opposite to each other, and between their poles are two soft-iron cores, on which are wound coils of insulated wire. The poles of the magnets are placed, the north opposite the south. Together with these, which are the fixed

parts of the apparatus (Fig. 28, A, B), an armature is employed, E, to which a reciprocating motion is given, which places it first in contact or nearly so with the two poles of one magnet, and then transfers it to a corresponding position with respect to the other magnet. The faces of the magnets and of the armature may be grooved to increase the area of the surfaces in contact or in close proximity.

In place of a reciprocating armature, a rotating one may be employed, so formed as to connect the

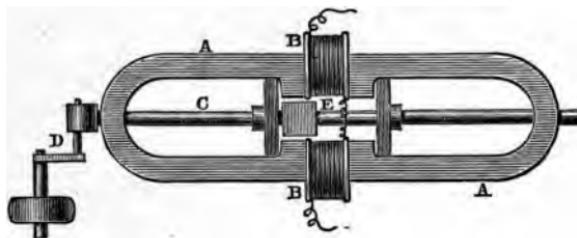


Fig. 28.—Varley's Machine.

north pole of one magnet with the south pole of the other, and, as it rotates, to couple the poles alternately.

In the figure a shaft is shown, C, reciprocally moved by the crank and power pulley, D. In addition to this design of a dynamo-electric machine, Mr. Varley has invented various other pieces of apparatus for the production of single or multiple circuits of current.

M. Gramme's Magneto-Electric Machines.

M. Gramme, of Paris, introduced about the year 1870 an entirely new kind of armature, which is essentially different from any of the forms previously in use.

It is a *complete ring of iron*, and the wire is wound upon it without a break all round the circle. If an iron ring has thus wound upon it an insulated wire, forming a complete coil, the ends of which are connected by soldering together, and if this coil and ring are caused to rotate upon a central axis between the poles of a magnet, there will be developed in the coils a curious electric state. Two currents are constantly flowing in the wire, such that as each point in the circuit arrives at a spot equidistant from the two poles of the magnet, that point in the wire has a maximum positive potential, whilst the point in the coil exactly opposite to this has a maximum negative potential. If now the exterior turns of the wire are denuded of covering, and a pair of springs made to press, one on each side of the ring, on a line directly between the poles, a constant current, similar to a constant fall of water, will pass in any outside circuit connected to the springs.

A Gramme ring may be made to work just as described, but in practice a different way of making up the ring is adopted.

M. Gramme makes his ring armature up as shown in Fig. 29, where A and A are the ends

of a coil or ring, composed of a great number of soft iron wires.

B B B are the coils of wire used by M. Gramme to cover the ring, it being found more convenient to make up the endless coil in sections, and then join them properly together, than to wind the wire from end to end and take the currents from the bared exterior. The upper part of the ring is seen fully coiled, while the lower side is being filled with coils. C C are the ends of the coils of wire, which

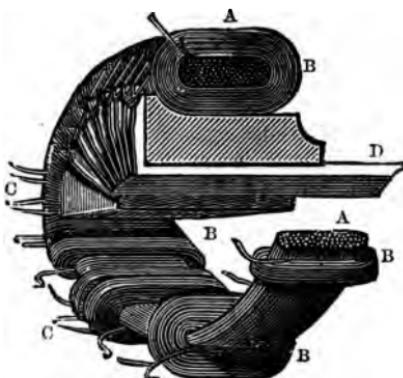


Fig. 29.—Gramme's Ring.

are taken out for connecting up after the ring is complete. At D is shown a number of copper plates radiating from the centre, and having fixed to them, in notches and with soldering, the ends of the completed coils of wire. These radiating plates are simply for the purpose of carrying the currents along the wooden axis to the point where they are taken off by a pair of contact pads or springs.

When the ring is complete, it will be entirely

covered with coils of insulated wire, and each coil will be connected to a copper plate. The connection is made up, however, in this way:—No. 1 coil has its inside end connected to No. 1 copper plate, and to the same plate is connected the outside or commencing end of No. 2 coil. The other end of No. 2 coil is then connected to No. 2 plate, and to the same plate is joined the outside end of No. 3 coil. This is continued around the circle, and the plates act exactly as if the wire was simply bared, and the currents collected direct. These radiating copper plates are also exhibited in the following views of the machine and its parts. The centre of the ring, after its ends have been drawn together, is filled up with a block of wood, through which runs the central spindle, and into slits in which the copper plates fit. It has been said, to aid the imagination, that the ends of the ring are drawn together, but the actual best mode of construction is to make up the ring of complete rings, or of cut wires, cut circularly and put into position so that there is no actual break at any part.

The length of wire in each coil will depend upon the size of the machine and upon the size of the wire. For No. 12 wire, well insulated, as much as 12 yards may be placed in each coil, and it is important that those coils are not very thick. They should be so thin as to allow about fifty to be placed on a 5-inch ring; but a great deal will depend upon the amount of care employed. Every part of the ring must be covered, and it will be

found best, as convenient in making up the central space equal to the exterior, to coat the copper plates with gutta-percha and varnish at their outer edges, and to place them between the coils against the ring itself. Fuller particulars for actual construction will, however, be found farther on.

Fig. 30 exhibits a section of the wire ring and coils, B B, upon a central spindle, C C. A A are the magnetic pole-pieces between which the ring re-

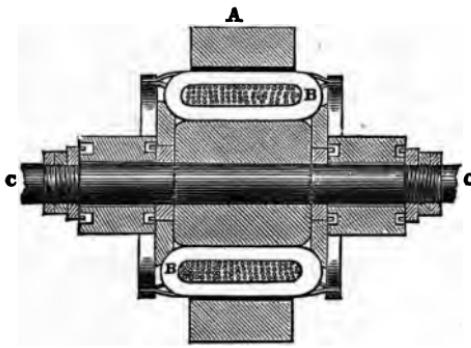


Fig. 30.—Section of Gramme's Ring.

volves. It will be observed that there are lock-nuts to secure the central portion in position.

Gramme's magneto-electric machines are now manufactured by M. Breguet, Boulevard Mont Parnasse, 81, Paris, in two or three forms to suit hand-power. The machines are very useful in laboratories, where a powerful current of electricity is often required. The best type are those with Jamain's laminated magnets.

Fig. 31 is a view of this machine. It will be seen that, as in all other forms of the Gramme ma-

chine, the currents are collected upon the *neutral line*, that is on a line passing between the poles of the magnet, vertically.

The following are a few instructions by which the amateur may be enabled to make for himself a very useful hand magneto-electric machine. The

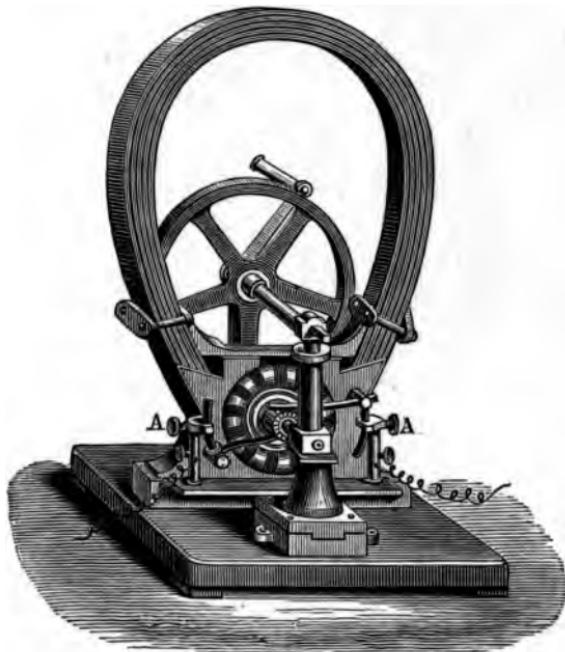


Fig. 31.—Gramme Hand Magneto-Electric Machine.

construction is not difficult, and doubtless will be undertaken by very many in want of some clean and handy apparatus to supersede the troublesome and often unwholesome battery.

Fig. 32 represents another hand-machine with

the Gramme armature. At present a similar machine is in the market from the laboratory of

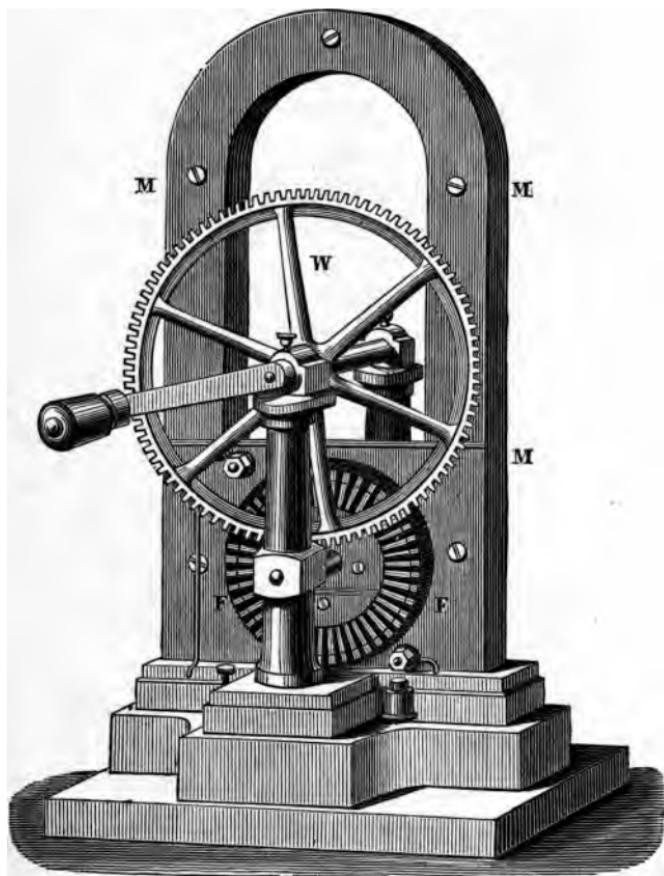


Fig. 32.—Gramme Hand Magneto-Electric Machine.

M. Breguet, at the price (in England) of £42. It the machine became known, and the demand were thus increased, there is no reason why the same

apparatus could not be made and sold for much less, and there is really nothing to prevent the handy amateur from making one for himself at an outlay of, at most, one-fifth of this.

The magnet is a permanent steel one. Some idea of the effect obtainable from the current, while the hand-wheel is driven at about 80 turns per minute, may be gathered from the fact that 14 in. of No. 36 B. W. G. platinum wire is brought to a white, glowing heat in a few seconds, and the turning of the handle at a fairly uniform speed may be easily kept up for almost any time required in ordinary experiments.

The general arrangement of the parts is indicated by the figure, in which *M M* is the permanent magnet, *w* the driving-wheel, gearing in a pinion on the spindle of *F F*, the Gramme ring. Screws are shown on the face of the magnet. These are employed when the magnet is made of two or more sections or layers of steel. A solid steel magnet is used in the machine made by M. Breguet, but it is undoubtedly better to make it up from two or more layers, although in this case constructional difficulties are much augmented. The teeth of M. Breguet's driving-wheel are cut obliquely upon the wheel rim. This is supposed to both decrease the noise and the risk of breakage; but the common wheel and pinion will be found to work the ring quite well. The base is solid, and it is imperative that it should be of some heavy dia-magnetic substance, if the machine cannot be clamped or

screwed to a table; this insures steadiness. The bearings or standards for the driving-wheel spindle also bear the ring spindle, and are of gun metal, and stout. The driving-wheel may be of brass, as, although cast-iron would do, it is very apt to give way at the toothed portion; brass or gun-metal is, therefore, to be recommended. The magnet should be of the best steel only, because steel of indifferent quality will not only fail to take up sufficient magnetism, but will lose its little strength quickly. Even the best steel will, in a few years, lose some of its magnetic strength, but it is no difficult matter to re-magnetise it. The wire used in the construction of the ring should be of the softest iron procurable, and the wire from which the coils are made should be of good copper of high conductivity. A high degree of accuracy is not necessary except in the making up of the ring, which must be truly circular and somewhat equally weighted.

Construction: the Magnet.—This part of the machine may be constructed in more ways than one. What is really wanted is a concentration of magnetic power at the ring-cheeks, $\wp\wp$, Fig. 33. Various forms of magnet might be employed to effect this, exclusive of electro-magnets; but as space in height is of little moment, and as the steel is most conveniently arranged vertically, the form of magnetic arrangement exhibited by Fig. 33 will be found to answer the purposes of the amateur best.

Fig. 33 shows the magnetic horse-shoe $M\ M$; the concaved cheeks, $p\ p$, may form part of the same mass of metal, but it will be found most easy in practice to make them of cast iron, and to screw them to the magnet legs as shown at the dotted lines on either side.

The feet or basis of the bent bar will be most easily screwed on from underneath, on account of the difficulty of getting wire coils upon the magnet in the process of imparting the necessary magnetic strength. The length of the bar complete may be 3 ft., its width 3 in., and its thickness $\frac{1}{2}$ in. It is best bent from rolled steel, of flat bar shape, although any other shape of steel will answer the purpose. It is well to know, however, that if the thickness be greater than $\frac{1}{2}$ in., the extra metal will be simply thrown away, for thick bars do not carry more magnetism than thin ones, and the difficulty of hardening will be greatly increased.

The bar should first be bent to horse-shoe shape,

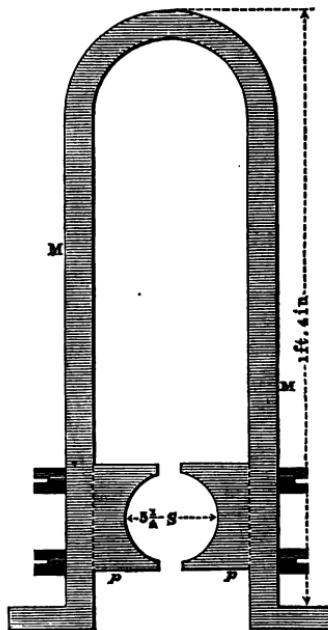


Fig. 33.—Small Gramme Magnet.

with two legs of equal length, and a space between them of $6\frac{1}{4}$ in. It may then be finished up, and have the screw holes for the cheeks and feet drilled. The screws may be ordinary $\frac{3}{8}$ in. bolts or screws. The hardening and tempering should then be proceeded with. It will be best to harden in a good charcoal fire, which must be of equal heat throughout the space occupied by the steel. As soon as a good blood-red heat is attained, plunge it into water, *bend first*, vertically. If this is not done as directed, it is probable that the bend will be softer than the other parts. The steel should be so hard that a file will scarcely cut it. Leave the "skin" on, and coat with sealing-wax or other varnish, except where the cheeks, *p p*, are to bear. If the magnet is to be magnetised by rubbing with another, do not yet coat with varnish.

Magnetism may be obtained in two ways: these are, first, by rubbing with a sufficiently strong electro-magnet; second, by passing round the steel a strong current of electricity. Very few people possess electro-magnets of sufficient strength to impart much vitality to so large a mass of steel, so that it will be best in most cases to use the voltaic current. It will be necessary to place upon the steel legs a pair of long coils of stout cotton-covered wire. No. 16 B. W. G. wire will answer very well, and as many as four layers ought to be in each coil, if its length does not cover the straight part of the steel. The battery power to employ may consist of just as many quart Bunsen's or bichromate

cells over 6 as the maker may possess. The more battery power the more magnetism, usually up to 20 cells. Ten cells of the simple bichromate battery in series will answer very well. The current may be passed for about a minute, and the circuit should be broken several times during this minute. The bar will be more difficult to magnetise, as it is harder; but the magnetism will last longer without variation. The poles should be crossed by a piece of iron during magnetism. Care should be taken that the wire from one leg crosses to the other like the letter S; if this is not attended to, and the wire is not wound as it is upon common electro-magnets, the magnetisation will be a failure and must be repeated under different conditions. If the wire be coiled upon the steel direct, it will be safest for the amateur to continue the coiling over the bend, when the direction must be correct.

The cheeks $\wp\wp$ are of cast iron. They should be 6 in. high by 5 in. wide, and thick enough to allow of the $5\frac{1}{4}$ in. circle, S, being cut from them. The space between their faces will thus be about half an inch or more. It will be best to have them cast to pattern, and then turned out. If there is convenience for annealing the cast iron, this may be done in a charcoal fire by heating to redness and cooling slowly. The circular space, S, should be as true as possible, for it is upon the nearness of the iron to the ring that the effects, to a great extent, depend. The backs must be made flat, to bear

flatly upon the clean flat surface of the magnet itself.

If the base is to be of iron, and the feet of the magnet are to be secured to it direct, they must be of brass, and brass screws must be used. If a wooden base is to be employed, the feet and screws may be of any metal. It will thus be seen that care is necessary not to close the magnetic circuit of the horse-shoe by any iron prolongations. The magnetic arrangement must be made steadily fast to the base, in position, and the rest of the work may be proceeded with.

The Ring, or Armature.—In the Gramme machine, the best form of ring consists of a flat bundle of soft iron wires, as is exhibited by Fig. 29, p. 74. The bundle of wires is a little more difficult to arrange in practice than one ring of iron. A good plan is to make it up of three 2-in. wide lengths of soft iron, one over the other. The innermost layer must be shorter than the second layer, and it must, in turn, be shorter than the outside layer. They are to form an almost complete ring, except a gap of $1\frac{1}{2}$ inch wide, to allow the coils of wire, B, to be slipped on. This gap, when all the ring is coiled, is then to be filled up with a piece of iron having a coil of wire upon it. This will complete the ring, the iron body of which must be continuous. The diameter of the ring, *outside*, is to be $3\frac{1}{2}$ in., and its diameter inside will thus be about $2\frac{3}{4}$ in., its width will be 2 in., and this size of ring will, when coiled with wire, give an outside ring

of 5 in. diameter or a little over, to fill the space S, Fig. 33, with clearance room.

The coils of wire, B B, Fig. 29, p. 74, are to consist of four layers of No. 16, silk or cotton covered. Silk will give the best coil, but cotton will answer, if well dried and steeped in melted solid paraffin. The layers of wire are to be $1\frac{1}{2}$ or rather less in width. They should be first coiled upon a former, or mandrel, having the same size as the ring body, and may be kept in shape by tying with silk thread and steeping in paraffin. They are to be slipped on, entering at the gap A A, Fig. 29, p. 74, until the ring is quite full, and their ends, C C, are to go to one side. The last coil, filling up the gap in the ring, is to be placed upon the piece of iron filling up the gap. This iron piece should fit into the ends so as to *spring them apart*, and must have a catch or taper filed upon it to keep it in place when it is tightly pressed in.

We have now the ring, with the wire upon it, and all the coil ends coming out at one side. There will be spaces at the outside not filled with wire, and they should be filled up completely with some such substance as melted pitch, to which some gutta-percha has been added. Concerning this, it should be remarked that these spaces will not exist if the contact plates of copper (D, Fig. 29) are placed *within* the ring, as there shown. It will, however, be easier for the amateur to leave the ends as they are, and to proceed to finish the ring as follows:—Turn a box or hard-wood drum to fit

the centre of the ring tightly. Let it be *very slightly* tapered and somewhat rough, to give a hold to the cement. Its length should be 7 in., and it should have a central hole to hold a tightly driven spindle of $\frac{1}{2}$ -in. round iron, of length over all 9 in. Let the wooden drum go through the ring until its thickest end is nearly flush with the wire coil and the small end projects considerably. Mark this place, take off, and in the wooden drum—commencing at the mark reached by the coils—make

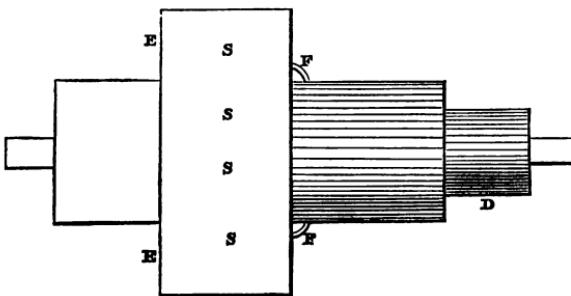


Fig. 34.—Gramme Ring and Contact Drum.

a number of slots or cuts with a saw. These cuts must be equal in number to the coils, and must radiate from the centre. Fig. 34 is intended to represent this. Now turn down the wooden drum for 2 in. at one end; reduce until the diameter is 1 in.; D, Fig. 34, will now represent this end so reduced. The depth of slots will be reduced also.

Into these slots must fit tightly pieces of thick sheet copper, D, Fig. 29, p. 74. These radiating slips must be driven in, and their edges should be

flush with the wood drum, both at the wide and reduced parts.

Now finish off, with a file, the edges, and connect the coils with the slips, and, to fasten on the ring, press the ring firmly on the spindle or drum. Melt a quantity of pitch and a little gutta-percha together, and fill in between the ring and the drum with it while very hot. When this sets it will keep the ring in position. Bring out all the cleaned ends of the coils, and commence by soldering the finishing or outside end of No. 1 coil to No. 1 copper slip; solder also to No. 1 slip the inside or beginning end of No. 2 coil. Solder the finishing end of this coil to No. 2 slip, and to the same slip the commencing or inside end of No. 3 coil. Continue thus until all the coils are joined to the copper slips, paint over with hot gutta-percha and pitch, and the ring with its connections is complete.

Fig. 34 will render this more clearly, where E E is the ring upon its axis, S S the coils, F F the ends of these joined to the copper slips, which lead along the drum, as the lines indicate, to D, which is the reduced end spoken of, with the slips having their edges flush with it.

Fig. 30, p. 76, will make the whole still more intelligible; but there are joints shown here which are intended to represent the way in which Gramme mounts the ring upon its spindle.

The actual construction of the spindle and the mounting are ordinary mechanical operations. The

toothed driving-wheel may conveniently have a diameter of 10 inches, and the pinion a diameter of $1\frac{1}{2}$ inches. The number of teeth is a matter of little consequence, but the pinion and wheel must agree as to *pitch* of the teeth, otherwise they will not run together. It will be found best to provide a gun-metal pinion, and to drive a pin right through its hub and the spindle. The height of the standards must be regulated nicely, to allow the 5-in. ring to revolve freely in the space *S*, Fig. 33. Nothing further should be done until this part is very exactly fixed in position. The distance between the centres of both spindles must be marked off on the uprights, and will always afterwards be correct. The lower spindle must be so set that the ring occupies as nearly as possible the central portion of the cheeks *PP*, Fig. 33.

As to the side of the machine at which the reduced or "contact" end of the wood drum projects, it is of little consequence; but it will be found most convenient to project it from the side opposite to the driving-wheel, because arrangements are to be fixed here for holding a pair of contact springs for collecting the current from the copper slips, as they project at *D*, Fig. 34.

When the ring is caused to revolve without the contact brushes passing upon the slips, there can be no circuit for currents, so that no currents are induced in the ring by the magnet.

Reference to Fig. 35 will render clear the way in which the contact spring should be arranged. One

presses upon the upper side of the drum end, and the other on the under side of the same. The edges of the radiating slips being flush with the circumference, there is not a heavy contact, but it is sufficient to collect the impulses as they are given off. These currents are constantly in one direction, and in this respect resemble a fall of water.

The springs shown at Fig. 35 are best made up from a number of stiff copper wires; but brass wires will answer, although they will be burned sooner if there is much sparking. The springs

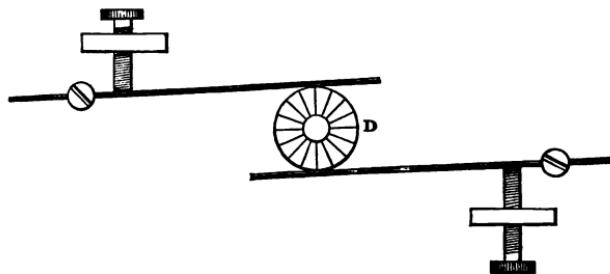


Fig. 35.—Contact Springs and Drum.

should be adjustable, through the screws fastening them, to expose fresh surface to the friction when necessary; and the thumbscrews shown serve to cause them to bear more or less heavily upon the axis. This part must be oiled.

From these contact springs the wires are taken to the binding-screw exhibited by Fig. 31. Stout covered wires should be employed to connect the machine to any piece of apparatus. M. Breguet supplies with the machine two rings, with stout and fine wire, for quantity and tension currents.

The currents must always be collected upon the neutral line.

De Meritens' Machine.

The construction of this machine provides for the armature a wheel, with a rim composed of segments of soft iron, wound as usual with wire at right angles to the iron segments, which are separated magnetically by strips of copper. All the segments are wound in one direction, but the outside end of one coil is joined to the outside end of the next, and the inside end is joined to the inside of the preceding coil.

This ring-tire armature is made to revolve inside the poles of a number of permanent steel magnets, arranged around in a circle parallel to the shaft of the revolving wheel. There is thus a regular succession of poles in the ring—N.S.N.S.

By this arrangement of coils, and the size of the coils in relation to the distance between the magnets, as one coil is approaching a north pole the next is approaching a south pole. Currents in *opposite* direction in these two *coils* are therefore produced, but by the mode of coupling the ends of the coils described above, these currents become in the *circuit* in the *same* direction. The current, however, is of course reversed, as any one magnet approaches and then recedes from any one pole, thus the machine produces currents which alternate in their direction.

The terminations of the wheel coils are soldered

to a pair of brass or copper rings upon, and insulated from, the central spindle. From these rings the current is taken off by copper brushes, usually composed of springy wire of large size.

It has been found that this machine produces remarkably strong currents in comparison with other machines of the same type. Were the sections composing the circular armature not insulated magnetically from each other as they are, some comparison might be made with the Gramme magneto machine, for the currents are induced under similar conditions, except that De Meritens employs a number of small magnets.

It is questionable if there really is any advantage in the De Meritens wheel armature, or in the insulating of the segments composing it, since such excellent work is done by the Gramme, with its complete ring.

CHAPTER V.

ELECTRO-MAGNETO ELECTRIC MACHINES.

HITHERTO we have only alluded to magneto-electric machines in which the current was produced by revolving coils of wire placed on soft iron cores, near fixed permanent magnets, or *vice versa*, revolving permanent magnets near fixed coils. It will be evident, however, that electro-magnets excited by currents from some source of electricity may be substituted for fixed permanent magnets; and, in fact, in 1845 Professor Wheatstone patented the substitution of electro-magnets for permanent magnets in magneto-electric machines for telegraphic purposes, and in 1852 Watt, in a patent, mentions the same idea; but no particular use seems to have been made of these suggestions.

Wilde's First Machine.

In 1863 Mr. H. Wilde, of Manchester, took out a patent for a machine for obtaining electric currents in which a large electro-magnet was excited by means of a battery, or by the current from the armature of a small magneto-electric machine, both

machines having Siemens' armatures, a commutator being arranged on the small machine, so as to give a current in one direction round the electro-magnet of the large machine. Mr. H. Wilde constructed a large machine on this principle, and appears to have first brought the principle before the public in two papers, read at the Royal Society on April 26th, 1866. "1. On some new and paradoxical phenomena in electro-magnetic induction, and their relation to the principle of Conservation of Physical Force. 2. On a new and powerful Generator of Dynamic Electricity."

The machine described consisted of a small magneto-electric machine, in which the magnets were permanent magnets, and the armature a Siemens' armature, standing on a large magneto machine, in which the magnets were electro-magnets, these electro-magnets being excited by the current from the armature of the smaller machine. The current from the large armature was consequently very powerful.

Fig. 36 shows an end elevation of this machine. $M M'$ is the small permanent magneto machine with its Siemens' armature C ; r and r' are the terminals connecting the commutator brushes of the small machine to the insulated copper bands of the large electro-magnet $E E'$. The wires z and z' show the external circuit connected to the contact brushes of the armature of the large electro-magnet.

Mr. Wilde carried his principle further, and made

and described a machine where the current from the



Fig. 36.—Wilde's Magneto-Electric Electro-Magneto Electric Machine.

first excited the electro-magnets of a second, and the current from the second excited the electro-

magnets of a third, the diameters of the Siemens' armatures being respectively $1\frac{5}{8}$ inches, 5 inches, and 10 inches.

The magnets of the small magneto-electric machine consist of six magnets weighing 1 lb. each, and the magnets of the 10-inch machine weighed 3 tons. The machine was furnished with two armatures, one for the production of "intensity," and the other for the production of "quantity," effects.

The intensity armature was coiled with a bundle of thirteen No. 11 copper wire 376 feet in length, and weighing 232 lbs.

The quantity armature was wound with copper plate 67 feet long, weighing 344 lbs.

The armatures were driven at the rate of 1,500 revolutions per minute.

When the large machine was excited by the medium, which in its turn was excited by the smallest machine, enormous effects were produced, and a piece of iron 15 inches in length, and $\frac{1}{4}$ of an inch in diameter, was melted. This was with the quantity armature. With the intensity armature the current produced melted 7 feet of No. 16 iron, and made a length of 21 feet red hot. The intensity armature was used for the electric light, with gas carbon half inch square, and the light evolved was sufficient to cast a shadow from the flames of the street lamps a quarter of a mile distant.

In March, 1867, Mr. Wilde exhibited a large machine of this description at the conversazione

of the Royal Society at Burlington House. The electric light was shown in great splendour, and iron rods 15 inches long and $\frac{1}{4}$ inch in diameter were fused.

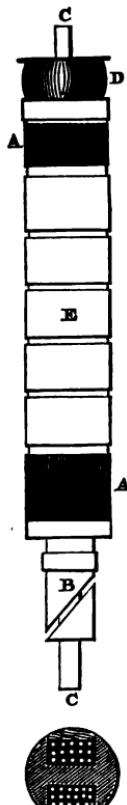


Fig. 37

Wilde's Armature.—Although the distinctive features of Wilde's machine lie in its magnets and arrangement, the make of Siemens' armature adopted by him calls for further explanation.

Fig. 37 exhibits this construction. The metallic portion of the armature is shown in the end view with cross section lines and the wire wound upon it in three layers. This cast-iron body extends from A to A, and in its longitudinal side grooves the wire is wound. The length of covered copper wire wound on is about 50 feet, and after the wire is on, a wooden packing serves to keep it in place and make up the circular form of the armature. Straps of brass encircle the armature at different intervals along its length; this prevents the coils from being forced outwards by centrifugal force. These are sunk in grooves made for them in the cast-iron body and wooden packing E. Two ends of brass are fitted to the ends of the armature, and to these brass caps are made fast the steel axis ends C C. D is the pulley by which motion is given to the armature from a strap.

The Commutator is of simple construction, and is shown at B. It is composed of two rings or sections of steel, fitted upon the steel shaft C, and insulated from each other. Upon this commutator or current reverser press the contact springs which take off the currents. One-half of the commutator is connected to the commencing end of the coil, and the other to the finishing end. As soon as the armature begins to move, a current begins to be induced in it, and for each revolution two opposed currents are given rise to in its coil. If the springs press upon the commutator, it will be seen, since the latter is separated by an oblique cut, that the springs must exchange parts at each half revolution, and as this exchange takes place at the moment when the armature reverses its current, the springs take off the current in one continuous direction.

CHAPTER VI.

DYNAMO-ELECTRIC MACHINES.

THE machine made by Mr. Wilde was an immense step in advance of all previous means of obtaining electricity from motive power, but a further step was very shortly to be made of still greater importance.

About the end of 1866, or beginning of 1867, the idea of employing the current, or a portion of the current, from an electro-magnetic electric machine to *excite the electro-magnets* themselves, thus dispensing with voltaic batteries or any primary exciting machine, occurred to Messrs. Varley, Siemens, and Wheatstone. Mr. Cornelius Varley patented this principle in 1866. In January, 1867, Mr. Werner Siemens communicated this principle to the Academy of Science at Berlin, and in February, 1867, Dr. W. Siemens communicated the same to the Royal Society. About the same time Professor Wheatstone published a similar idea. But all these gentlemen were, as far as printed publication went, long anticipated by Sören Hjorth, of Copenhagen, who in 1854 had patented this principle very distinctly, giving drawings in his specifications.

Mr. Murray also, in the *Engineer* of July 20, 1866, states that he, using only a single machine, passes the currents from its armatures through wires coiled round the permanent magnets in such a direction as to intensify their magnetism, which in its turn reacts upon the armatures and intensifies the current.

On February 14, 1867, two papers on this subject were read before the Royal Society. The first, received February 4, was "On the Conversion of Dynamical into Electrical Force without the aid of Permanent Magnetism," by C. W. Siemens, F.R.S.

The author says, "An experiment has been suggested to me by my brother, Dr. Werner Siemens, of Berlin, which proves that permanent magnetism is not requisite in order to convert *mechanical* into *electrical* force; and the result obtained by this experiment is remarkable, not only because it demonstrates this hitherto unrecognised fact, but also because it provides a simple means of producing very powerful electrical effect." After describing the principle of a dynamo machine, in which a single element of a battery was used to start the magnetism, he says, "The co-operation of the battery is only necessary for a moment of time after rotation has commenced, in order to introduce the magnetic action which will thereupon continue to accumulate without its aid. The mechanical arrangement best suited for the production of these currents is that originally proposed by Dr. Werner

Siemens in 1857 (see 'Du Moncel sur l'Electricité,' 1862, page 248), consisting of a cylindrical keeper hollowed at two sides for the reception of insulated wire wound longitudinally, which is made to rotate between the poles of a series of permanent magnets, which latter are at present replaced by electro-magnets.* On imparting rotation to the armature of such an arrangement, the mechanical resistance is found to increase rapidly to such an extent that either the driving strap commences to slip, or the insulated wires constituting the coils are heated to the extent of igniting their insulating silk covering.

"It is thus possible to produce mechanically the most powerful electrical or calorific effects without the aid of steel magnets."

The second paper, received February 14, was "On the Augmentation of the Power of a Magnet by the reaction thereon of currents induced by the Magnet itself," by Charles Wheatstone, F.R.S.

The author states, "In the present note I intend to show that an electro-magnet, if it possess at the commencement the slightest polarity, may become a powerful magnet by the gradually augmenting currents which itself originates." He then describes a machine the same as the electro-magnetic part of Mr. Wilde's machine, and then goes on to show that little effect is produced by temporarily exciting the electro-magnet if the circuits of the armature and magnet are separate. But if the

* It being understood that the current from the armature is by suitable commutator led round the electro-magnet coils.

wires of the two circuits (*i.e.* the electro-magnet and armature coils) be so joined as to form a single circuit, in which the currents generated by the armature, after being changed to the same direction, act so as to increase the existing polarity of the electro-magnet, very different results will be obtained. The force required to move the machine will be far greater, showing a great increase of magnetic power in the horse-shoe; and the existence of an energetic current in the wire is shown by its action on a galvanometer, by its heating 4 inches of platinum wire .0067 in. diameter, by its making a powerful electro-magnet, by its decomposing water and other tests.

The principle thus brought prominently forward by Dr. Siemens and Professor Wheatstone, and previously patented by Sören Hjorth and Cornelius Varley, and published by Murray, was soon brought to bear in the construction of an infinite variety of machines for obtaining electricity from mechanical motion without the aid of permanent magnets or batteries, and the name of dynamo-electric machine has been given to them in distinction from magneto-electric machines, where permanent magnets are employed. Dr. Siemens' machine, constructed to show the principle, consisted of flat electro-magnets like Wilde's, with the Siemens' armature, only the machine was laid horizontal instead of vertical.

Mr. Wilde soon adapted this principle of reaction to his machines, dispensing with the per-

manent magnets, but still using a small electro-magneto electric machine, as well as a large one, the current from the armature of the small machine being made to pass round the wire of both machines to excite their electro-magnets. The current from the armature of the large electro-magnets was used alone for external purposes.

As the heat is sometimes great, some of Wilde's machines have the central shaft hollow, and a current of cold water is caused to pass through it, and also through the tubular large electro-magnet.

These machines have had their chief application in electro-metallurgy, but they have also been used for the production of electric lights.

Ladd's Dynamo-Electric Machines.

Mr. Ladd, of London, made a machine, Fig. 38, which differed from Wilde's in having two flat

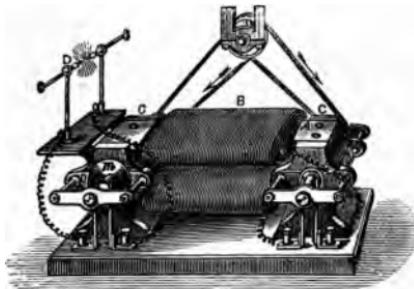


Fig. 38.—First Form of Ladd's Machine.

electro-magnets, B, placed parallel, with Siemens' armatures, C C, revolving at each end of the system, Fig. 38. The current from one of the armatures

excited the electro-magnets, and the current from the other was used for external purposes. Mr. Ladd also constructed the form of machine exhibited in

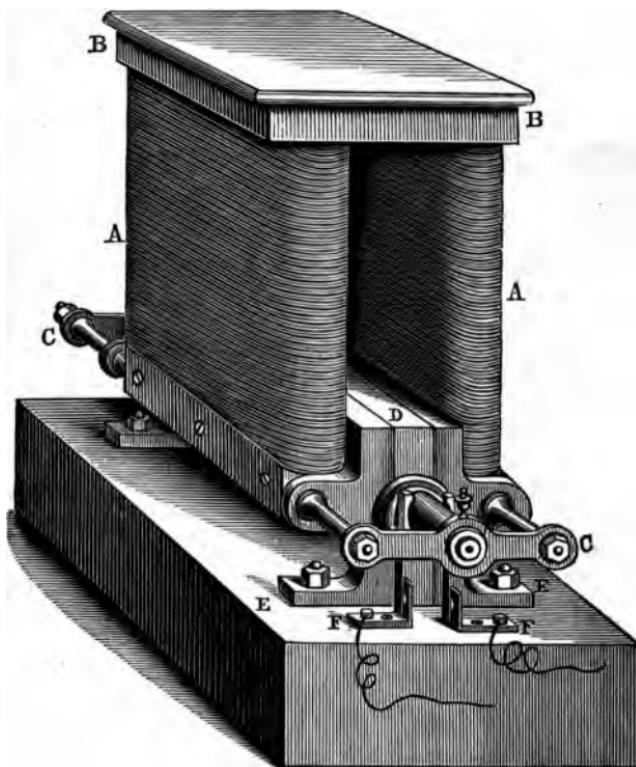


Fig. 39.—Ladd's Machine.

Fig. 39, with two armatures fastened upon one shaft, one armature is used to excite the electro-magnet and the other is reserved for outside work.

Holmes's Dynamo-Electric Machine.

In 1869 Professor Holmes made a dynamo-electric machine for the Trinity House. The machine consisted of ten electro-magnets fixed to a revolving shaft, the poles of the magnets, turned outwards from the shaft, passing as the shaft revolved by fixed coils. A part of the current from the coils was passed along the shaft to the coils of the electro-magnet. It was intended for use in the South Foreland, and gave 2,800 candle power, but was not used.

From this point the author does not pretend to give descriptions of the various machines in the order of the date of their invention.

Gramme's Dynamo-Electric Machine.

The Gramme magneto-electric machine has been described; the Gramme ring armature being the essential feature of the arrangement. In the Gramme dynamo-electric machine the ring is the same in principle and form, but the magnets are electro-magnets, formed by bars magnetically joined by the frame of the machine, and the insulated wire on them is wound in such a way that the mass of metal joined to the *centres of the bars*, or groups of bars, are the *magnetic poles* when the magnets are excited. The current from the coil is led through the electro-magnet coils as in most dynamo-electric machines.

Fig. 40 is a view of a complete Gramme machine of the smaller type. It is much used in electro-plating (see the writer's "*Electro-plating*"), and in illuminating workshops. Its power is over 2,000 candles. Its weight is 1 cwt. 2 qrs. The armature should make 1,600 revolutions per minute, with a horse-power of 1½. Its price is £60 to £70.

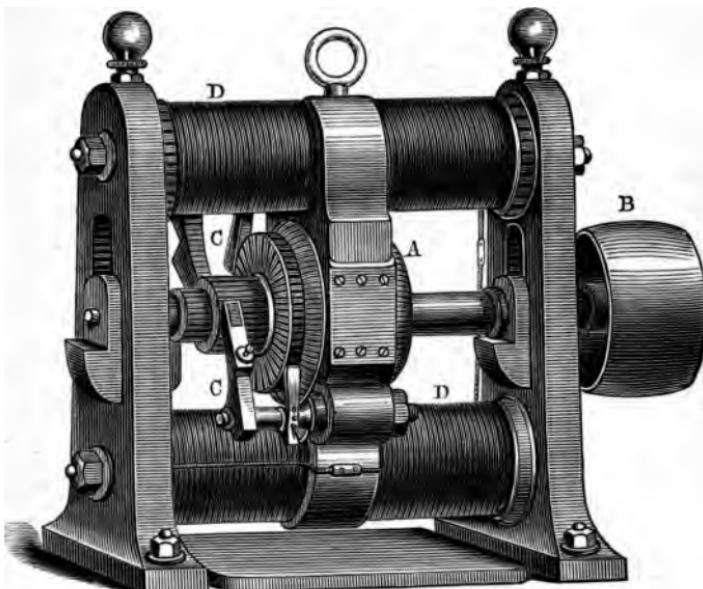


Fig. 40.—Small Gramme Machine.

DD are electro-magnets, connected through the framework, and this brings the poles to the cast-iron cheeks which embrace the ring above and below. The system composes, therefore, one electro-magnet. A is the ring, CC the collecting brushes, B the driving pulley. The height of this

machine, as shown, is 23 inches. Length 25 in., width, 13 in.

Fig. 41 is an end sectional view of a Gramme machine of a small size. A A' are bars, of the electro-magnets, wound with stout copper wire. These bars form the two poles of a magnet, as they are

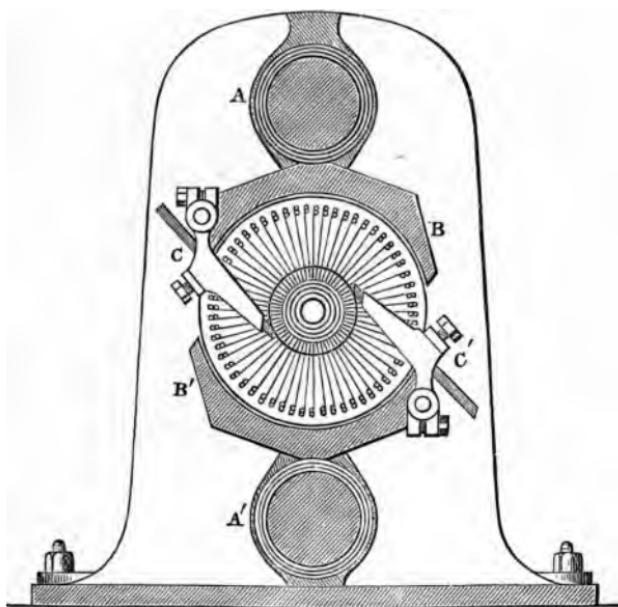


Fig. 41.—Gramme Machine. Section.

connected together at their ends, through the framework of the machine. B B' are the pole pieces, or cheeks, which embrace the ring for about seven-eighths of its circumference. The ring revolves very near to them. C C' are the collecting pads, brushes, or springs. These usually consist of a bundle of

hard copper slips, or hard copper wires, passed through, secured by, and regulated as to length through the holders shown. These brushes need attention about once a day, when the machine is in constant action. They must not press heavily upon the axis, but the pressure should be increased until most of the sparking is taken up. These sparks, given off by slight breaks in the circuit, soon burn the brushes and contact pieces.

Gramme's machines are now made in several sizes, to give from 2,000 to 16,000 candle lights, with horse-power required of from $1\frac{1}{2}$ to 6, and in weight from 1 to 8 cwts. Cost, from £70 to £300.

Fig. 42 illustrates one of the large machines constructed by Gramme, for electro-plating and cognate purposes. It has 6 bar magnets, 2 rings, and weighs 1,540 lbs. The copper wire upon all the magnet bars weighs 400 lbs., and upon the ring 80 lbs. It is found to give an electric light of about 4,000 candles, but is not well adapted for electric illumination or for very high speeds.

Two of Gramme's 16,000-candle power machines are employed to burn the electric candles on the Thames Embankment. One of these machines burns 20 "candles." The connections in the ring of this larger machine are not made all on one side. There are 120 radiating slips, 60 on each side of the ring. These lead to two collecting cylinders, and four collecting pads press upon these cylinders to take up the currents.

Work of the Gramme.—In a communication to the Academy of Sciences, M. Tresca gives an account of a series of experiments which he had instituted for the purpose of determining the work performed by the dynamo-electric machines of

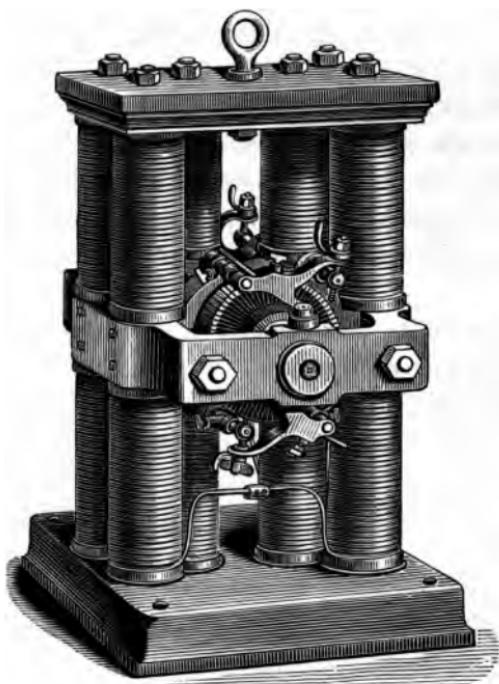


Fig. 42.—Large Gramme Machine.

M. Gramme. His experiments had reference to two machines emitting light equivalent to 1,850 and 300 Carcel candles respectively. These particulars will be found in *Van Nostrand's Magazine* for June, 1876.

A similar series of experiments were carried out at the French Northern Railway dépôt, with Gramme machines of 50, 100, and 150 Carcel lamp power respectively. The power necessary to drive the machines was ascertained by a comparison with engines driven by gas or steam, of 2, 3, or 4 horse-power, used either separately or coupled. Previous determinations, carefully ascertained, however, with a Prony dynamometer, had given the relative volume of gas consumed to the power derived (*i.e.*, useful work), all the conditions remaining the same.

The lamps employed in the experiments were of the Serrin type, and answered the purpose remarkably well. The following results were obtained. The horse-power is given in Force de Cheval = 0.9876 of a horse-power.

Number of revolutions of bobbin per minute	Dynamo-Electric Machine of		
	50-Candle Power.	100-Candle Power.	150-Candle Power.
1,650	800	800	

Power necessary to secure a steady light—

With carbons 0.007 m. apart	2.2 ch.	2.4 ch.	2.5 ch.
Ditto 0.009 m. apart	„	2.6 ch.	2.7 ch.

Consumption of carbons, including waste—

With carbons 0.007 m. apart—

At Positive Pole	„	0.090 m.	} 0.135 m.
Ditto at Negative Pole	„	0.045 m.	

With carbons 0.009 m. apart—

At Positive Pole	„	0.060 m.	} 0.090 m.
Ditto at Negative Pole	„	0.030 m.	

The following figures will be of interest as exhibiting the comparative cost of electric lights

and gas, as ascertained through the experiments undertaken by the Northern Railway Company of France.

Taking, for example, the lamp of 150 Carcel candles, and allowing it to emit light for 10 consecutive hours in some spacious hall or railway dépôt: 150 Carcel candles will require a consumption of 150×0.105 mc. of gas per hour, equal to 15.75 m., which, at the rate of 0.36 fr. per cubic metre, would constitute an expense of 5.70 frs. In the use of electricity for the illumination, 150 Carcel candles require 2.7 ch., which, at the rate of 0.09 fr. per horse-power per hour, including cleaning and lubrication, the expense would amount to 0.24 fr. Adding to this 0.09 fr. for carbons, 0.45 fr. for wages to the employé, and 0.20 fr. for the interest and liquidation of the expense of instalment, the total amount would be 0.98 fr., or, in other words, between one-fiftieth and one-sixtieth of the expense involved when using gas for the illumination.

An electric light of 150 Carcel candles lights up advantageously a circle of about fifty metres in diameter, and it is evident the illumination by electricity, being so much superior in intensity, ought to be more economical than gas, since the illumination of the *same area* requires the light of more than twenty-five gas jets, consuming 105 litres per hour.

The best make of Gramme machine now produced, of the 6,000-candle type, is, length, 1 ft. 11 in.; breadth, 1 ft. 3 in.; height, 1 ft. 8 in.; weight,

3 cwt. 1 qr. 22 lb., horse-power absorbed, 2·5 ; revolutions per minute, 850 ; light in standard candles, condensed beam, 6,400 ; diffused beam, 4,000 ; *light produced per horse-power*, in standard candles, condensed beam, 2,560 ; diffused beam, 1,600.

The following are a few particulars given by the British Electric Light Company of Gramme Dynamo-Electric Machines.

Class	Light in Standard Candles.	Horse-power required.	Revolutions per Minute.	Weight	Extreme Dimensions.			Price.
					Length.	Breadth.	Height.	
O	800	$\frac{1}{4}$	1,600	cwts.	ft. in.	ft. in.	ft. in.	£
M	2,000	$1\frac{1}{2}$	1,600		1 6	1 2	1 4	60
A	6,000	$2\frac{1}{2}$	900		1 6	1 2	1 4	60
C	+15,000 *25,000	5	700	8	3 4	2 4	1 4	75
D		8	1,200					
	+25,000 *45,000	8	300	20	3 2	2 8	2 8	—
		13	500					

+ Tension.

* Quantity.

The intensity of light here quoted is approximately that given by a machine working with a Serrin lamp in good order. When other lamps are used, the intensity of light may differ from the above results. The figures are given as a guide only.

Gramme's Distributor Machine.

For the Jablochkoff candle, consisting of two carbons placed parallel and insulated from one another, which will be described farther on, alternate currents are required, and for this purpose, and for producing currents in several separate circuits,

M. Gramme devised a machine called the "distributor," which is used in conjunction with an ordinary Gramme machine.

The machine in external appearance resembles a wooden drum fixed by feet and bolts to a firm base.

Directly inside the drum surface is a flat ring of iron, divided into 8 sections, and half of each section is coiled alternately right and left with covered wire. The whole outside system is therefore simply 8 flat curved electro-magnets. Within this circle, projecting from the axis of the machine like the spokes of a wheel, are 8 wide and flat electro-magnets, which are also wound with wire alternately right and left, their exterior poles being thus alternately north and south. This central system is caused to rotate, and into the coils of the magnets is passed the current from an ordinary Gramme generator. There is no actual connection between the revolving system and the outer 8-section ring. The electro-magnets act as usual by induction upon it, and cause each section to give off alternate currents. These sections may be subdivided again into right and left subsections. The subsections may also be wound in one direction as in the Gramme ring. The wires of the central rotating electro-magnets form one continuous circuit, and the current is simply passed into it by a pair of copper wire brushes pressing upon two copper rings connected to the ends of the circuit. The speed is from 300 to 600 revolutions per minute, with horse-power of from 10 to 16, and

it is usual to drive both generators and distributors from one engine. These machines give no trouble whatever, and may be had to cut a current into 32 parts or circuits for as many or more lights.

Taking two notable examples of the application of this machine, it was the one used to distribute the main currents to Jablockhoff's candles as employed lately in Paris. It is the machine in use in the illumination of the Thames Embankment. In this latter instance of electric illumination, the main generators (of which there are two) are 16,000-candle power Grammes; the current from these is passed into the distributing machines, which send alternate currents into 4 circuits, in each of which there are 5 candles.

Gramme's Combined Exciting and Dividing Machine.

This is a new form of the Gramme apparatus recently introduced. In it the exciting ring and "distributing" or "dividing" coils are combined and form one machine. Figs. 43, 44, 45, and 46 represent this apparatus.

The machine, a general view of which is shown by Fig. 43, is arranged as follows: On a cast-iron foundation are fixed two plates of the same metal, almost circular in shape, forming the standards upon which the electrical parts are mounted. They are connected together by six square bolts, and are provided with bearings for the main shaft (see

longitudinal section shown in Fig. 44). One of these plates is furnished on the inner side with a circular rib on which are mounted the electro-magnets for exciting the ring, as shown by the cross section Fig. 45. As in the model previously described, the coil for the alternating currents rests on the square bolts connecting the end plates of the frame with packing pieces of hard wood. One end

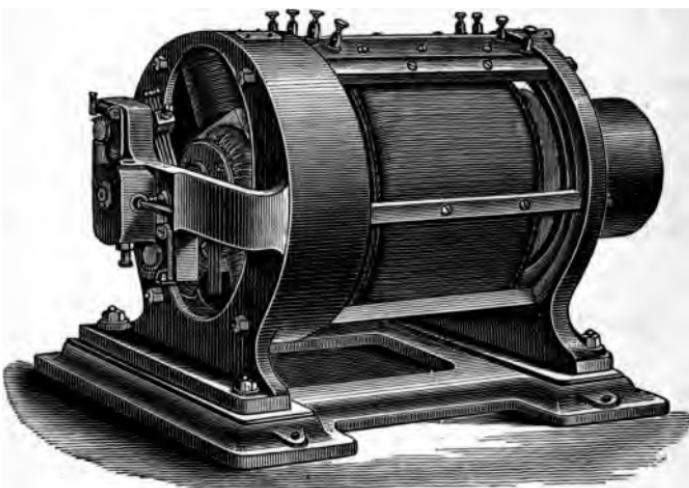


Fig. 43.—Gramme's Combined Machine.

of the frame thus carries the electro-magnets of the exciter, while the central portion supports in position the large flat coils of the distributor, shown in cross section in Fig. 46. Upon the main shaft is mounted, at one end, the exciting coil, which revolves between the poles of the fixed electro-magnet, see Fig. 45. The central portion of the main shaft carries a hexagonal sleeve upon which

are bolted the six electro-magnets of the large distributing coil, shown in cross section in Fig. 46. The shaft thus carries at one end the exciting coil and upon its central portion the six electro-magnets, radially arranged, which induce the currents in the distributing coils, see Fig. 44. Wide bearings are employed, and in the larger machines a system of automatic lubrication is in use.

An arm carrying a wire brush, shown in the

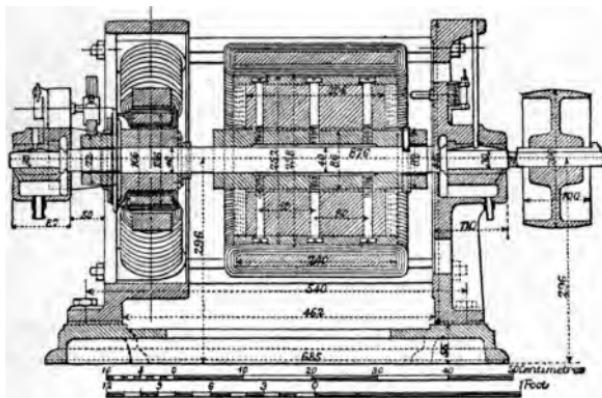
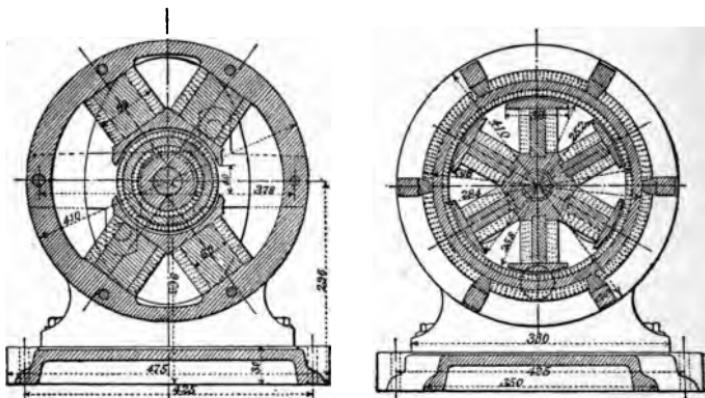


Fig. 44.—Gramme's Combined Machine.

longitudinal section, Fig. 44, serves to place in communication the coils of the moving electro-magnets with the exciting ring. The current is collected and transmitted by small brushes of silvered copper wire. The brushes are worked by means of a small endless screw. For regulating the power of the machine, a copper wire, the length of which can be varied at will, is introduced between the exciter and the electro-magnets. The method of coiling

the wire differs slightly from that adopted in the other machines, as instead of winding only one wire two are coiled, in order to obtain by this mode of coupling tension currents for small lights, or quantity currents for large ones. Two types of this machine are now manufactured. The smaller weighs 616 lbs., and supplies 12 candles of from 20 to 30 Carcel burners, or 8 candles of from 40



Figs. 45 and 46.—Gramme's Combined Machine.

to 50 burners. The larger machine weighs 990 lbs., and furnishes power of 24 candles of 20 to 30 burners, or 16 of 40 to 50. The following table contains the results of some recent experiments with these machines:—

Number of revolutions per minute.	Horse-power expended.	Number of lamps.	Power of each light in Carcel burners.
1400	5	12	28·5
1425	6	8	43·0
1200	4	6	48·5
1000	13	16	48·0
1020	13	16	51·3
1200	14	24	31·0

With a machine specially arranged for small lights, there have been obtained, with a speed of 1,250 revolutions, 14 lights of 20 Carcel burners each, with an expenditure of 4'66 horse-power. The candles employed had carbons 3 mm. (12 in.) in diameter. In all the experiments made a much steadier light was obtained than that given by the machines employing an independent exciter.

A recent application of this machine has been made on board the *Cosmos*, a ship recently built by Messrs. Inglis & Co., of Glasgow and Greenock, for the *Messageries Fluviales à Vapor*, in South America, for running on the rivers Plata and Uruguay. The machine employed is capable of producing 8 large or 12 small lights, and running at a speed of 1,500 revolutions per minute, maintains 8 lights of 50 Carcel power, each with an expenditure of 6 horse-power. The lights are distributed as follows:—Three in the upper saloon, three in the lower saloon, one on the landing of the stairway leading from the upper to the lower saloon, and one over the gangway. The machine, which is fixed on deck amidships and under the paddle-wheel shaft, is driven by a vertical engine with a cylinder 4½ in. in diameter, and 4½ in. stroke. The experience obtained at the trial of this light was in every way satisfactory.

Siemens' Machine.

This machine has gained considerable praise, especially in England, by its excellent performances at the trials at the South Foreland lighthouse

by the Trinity Board. The apparatus is made in several sizes; the largest giving a luminous inten-

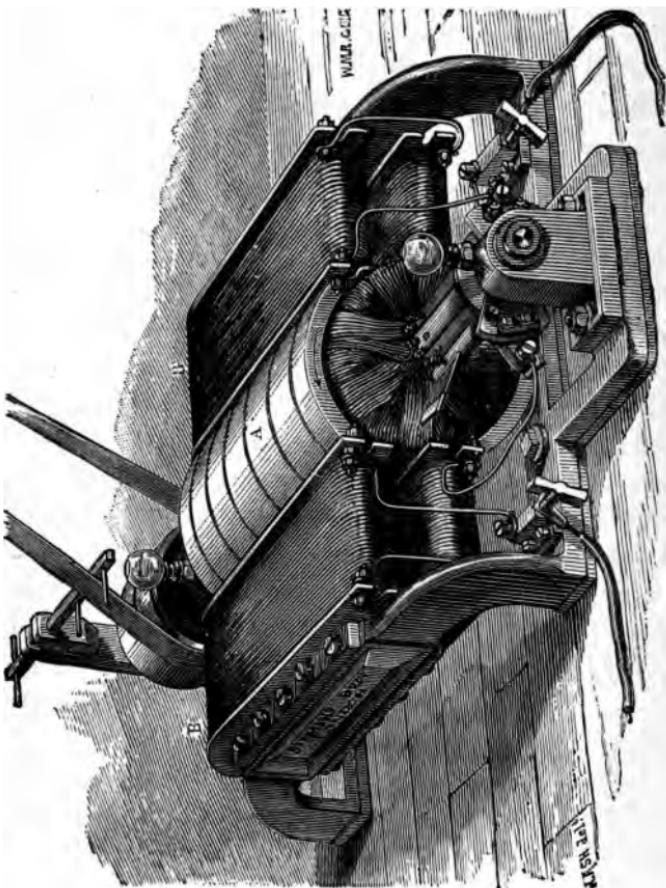


Fig. 47.—Siemens' Machine.

sity of 14,000 candles, and the smallest 1,200 candlelight.

Fig. 47 represents the smallest machine, and the principle upon which its parts are arranged being

the same as the other sizes, the same view will serve for all.

B B are the flat bobbins of wire around a series of bent iron bars, A, crossing from one side of the machine, and curving over the armature to the other. There is, in fact, one large electro-magnet,

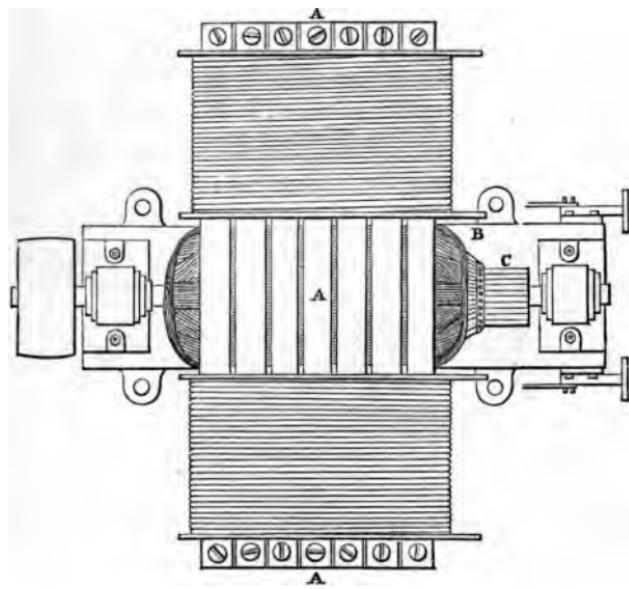


Fig. 48.—Siemens' Machine. Plan.

made up from 5 iron bars above and 5 below. The ends of these bars are secured, as shown, to the side frames by 10 screws on each side as seen. There are thus four flat bobbins of wire, and the poles of the large electro-magnet are, one directly above the armature, and the other directly beneath.

The end of the armature, which is of somewhat

peculiar construction, is also exhibited, and upon its axis is the collecting drum, against which the contact pads of copper slip press, to take off the currents.

Fig. 48 is a plan of the same machine, where 7 electro-magnet bars are shown, the machine being sometimes made with 7 bars. The wire bobbins will be clearly seen in position. B is the end of the armature, and C the collecting drum as before mentioned. The armature in this machine is a

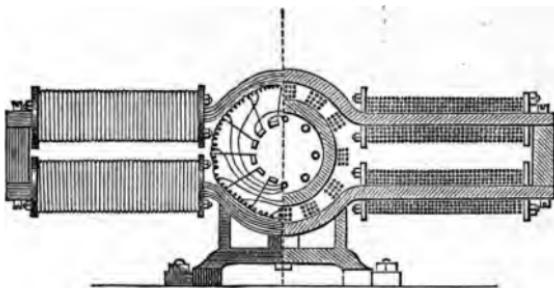


Fig. 49.—Siemens' Machine. Section.

cylinder of iron, and the wire is coiled upon it lengthwise, the ends of the different coils being fastened to copper radiating slips at C. This cylinder of iron is hollow, and is arranged so as to revolve with the central shaft; thus the whole central wire-coiled cylinder revolves, while the electro-magnet remains fixed.

Fig. 49 is a sectional end view of the machine, where the true shape of the electro-magnet bars will be seen. They are curved so as to embrace the armature very closely, as shown, and the flat

bobbins of wire encircle them. These wire bobbins are shown, the right-hand pair in section. In the central chamber is the armature, the half of which is in section to show the wire coils, and the left-hand half with the ends of the left-hand coils shown fastened to the tops of the radial slips of the collecting drum. The wire is wound on the armature in a longitudinal direction, and in a peculiar grouping invented by Häfner-Alteneck. Each convolution is parallel to the axis of the cylinder, and the wire is wound in six sections of two coils each, leaving twenty-four ends which are connected up, so that two of these ends are brought to each of the segments of a circular commutator having twelve divisions. But all the coils are connected to the several segments of the commutator in such a manner that the whole six double sections form a continuous circuit, but are not joined in the mere succession in which they are placed on the armature, but in a peculiar way difficult to explain without diagrams.

The joining is so arranged all round the armature, that the coils are placed in proper relation to each other, so that their impulses may be collected by the contact brushes, which are placed as far from the neutral line (neutral magnetic line) as is found to give the strongest current with the least amount of sparking.

Fig. 50 shows another kind of armature as fitted to Siemens' large 14,000-candle machine. In this machine the iron of the armature is itself

fixed, and the wire coils, arranged and made fast to a cylinder of German silver, *revolve over it*. The difference is not much, but the machine is rendered, in the opinion of its inventor, cooler and more effective in use, because in this case both the poles and the iron of the armature *remain fixed*. The wire coiling is almost the same, but there are double sets of supports; that is, a pair of bearings in which the ends of the central shaft, to which the armature cylinder is made fast, are fixed, and a pair of

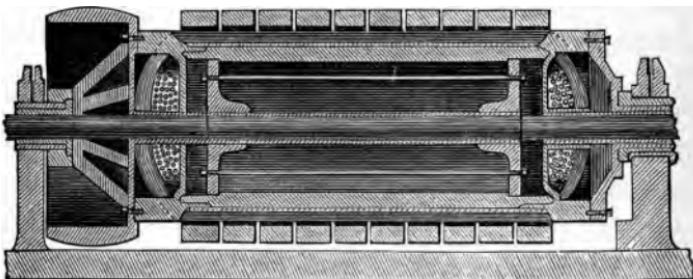


Fig. 50.—Siemens' Machine with Fixed Armature. Section.

ordinary bearings in which *revolve* the ends of the German silver or wire cylinder over the fixed one. The figure shows the real bearings only, also the embracing electro-magnet bars.

Although the large flat electro-magnet of the Siemens' machine is to all intents a closed electro-magnetic mass, with no terminal poles, as ordinarily found in electro-magnets, poles exist in a line passing vertically through the centre of the armature and the machine, the same way as in the Gramme the poles are in the masses attached to

the centre of the bars. When the machine is set in motion there is little resistance, but a few turns of the armature is sufficient to collect in its coils, from the feeble induction of the residual magnetism, enough electricity to greatly strengthen the magnetic poles, which induce stronger currents in the coils, and this goes on, on the principle of mutual accumulation, until the magnet is saturated and the machine gives its strongest current.

The magnetic poles act strongest upon the coils just as they pass the vertical line passing through the axis, and the weakest currents are produced as the coils pass the horizontal line. These are called the maximum and minimum points. Currents are thus induced as the convolutions of wire approach either of the magnetic poles. The currents are at once taken off by the contact brushes, and pass in a constant direction through all the coils of the electro-magnet, from the two ends of which the current is taken for the external circuit in the usual way. All the wires employed are, of course, insulated, or covered with gutta-percha, tarred hemp, or cotton and silk.

The new Siemens' machine is made in three sizes, designated by the makers as A, B, and C, to which the following figures refer :

	Revolutions per minute.	Horse-power required.	Light effect, standard can.	Weight, cwt. qrs.	Cost, £ i
“A.”	850	2	1,200	2 2	60
“B.”	650	4	6,000	3 3	112
“C.”	360	8	14,000	11 2	250

Several lighthouses are now illuminated solely by the above machines. The smallest size would appear to be in most favour, as they may be readily coupled together, which is often required in thick weather to produce a powerful light, which would be unnecessary in clear weather. They have been adopted by the Trinity Board, at the Lizard lighthouse, where six of the small machines are fixed. Of the competitive trial brought about by the Trinity Board, to determine the most economical machine for lighthouses, superintended by Professor Tyndall and Mr. Douglas, engineer to the Board, it will be unnecessary here to speak at length. The Siemens is known to have given the best results, but would doubtless have been run very closely by the Gramme had not the specimen of that machine tried been of an inferior type to those now produced.

Of the working of Siemens' machines the author has had practical experience, and can testify to their excellent performance with one lamp in circuit. The machines keep cool, which is a great advantage in continuous working.

The Siemens' Alternating Current Machine.

Dr. Siemens in 1878 patented an alternating current machine, Fig. 51. It consists of a central disc carrying bobbins. This disc is on a shaft and revolves between two sets of electro magnets ranged in circles on each side of the disc, having their axis parallel to the shaft. The bobbins have no

iron cores, and the heating caused by the magnetising and de-magnetising of the iron is thus

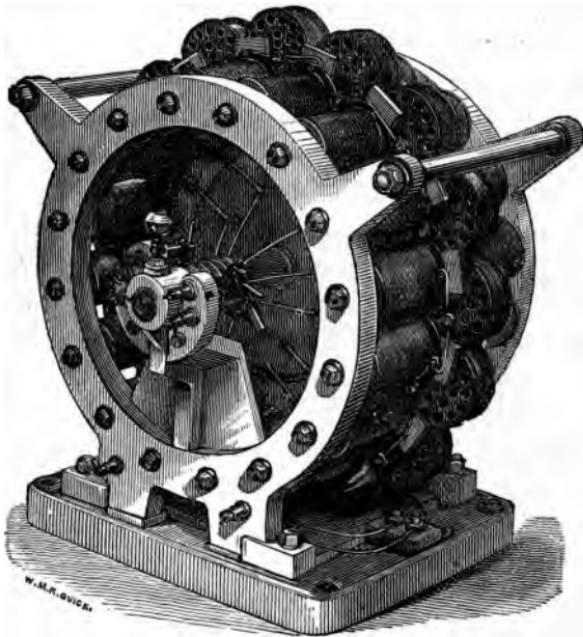


Fig. 51.—Siemens' Alternating Current Machine.

avoided. The electro-magnets are excited by a small Siemens' continuous current dynamo machine.

Maxim's Machine.

Fig. 52 represents a dynamo-electric machine, patented by Mr. Hiram S. Maxim, of New York.

It will not be difficult to trace in the arrangement of the parts a distinct resemblance to the Siemens' machine.

The curved electro-magnet bars are bolted to a

stout cast-iron projection from the base, and form, in fact, the framework of the machine. They extend upwards, are curved at the middle to provide a cylindrical chamber for the armature, and are finally bolted to a metallic plate forming the crown of the machine. Just above the base are placed a pair of flat wire bobbins, closely embracing the electro-magnet bars, and above the curved

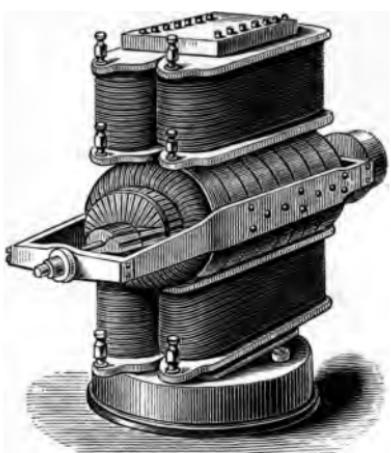


Fig. 52.—Maxim's Machine.

central portion are fixed another similar pair of bobbins. This forms the electro-magnetic system of the apparatus, which is very simple so far.

Along the sides of the bars, just opposite to the central line horizontally, are bolted two stout side frames. These carry

between their ends the supports or bearings of the central spindle.

The armature in this machine is similar to that of the Häfner-Alteneck armature in the Siemens' machine. It is a hollow cylinder of iron. The wire is coiled upon it lengthwise in sections, and these sections are connected to radial metallic contacts, as in Gramme's armature. The brushes are fastened in a very well-arranged frame, which is so

mounted as to be adjustable, so that the machine may give the minimum of sparking. The collectors themselves are of thin sheet hard-rolled copper, in several layers to give elasticity. Hard-drawn copper wire is also used, and is, perhaps, better in wear than copper sheet. The collecting pads, or brushes, thus made up, are clamped by two bolts in position as required to press slightly or strongly upon the collecting axis. This machine is very compact, occupies even less space, power for power, than the smaller Siemens, and is well adapted for the dissipation of heat. The horse-power required is about 2. This would appear to be the machine to which the United States Electric Light Company have pinned their faith.

Wilde's Dynamo-Electric Machine.

Mr. Wilde, in 1866, took out a patent which forms the basis of a dynamo-electric machine, which he eventually completed in its design in 1873. It consists, for the framework, of two cast-iron circular plates, placed vertically and kept the requisite distance apart by stay rods. Each plate carries, projecting from its inner face, a series of electro-magnets, sixteen in number. These fill up the greater part of the space between the frames. Through the centres of the frames is passed the shaft, which carries a large cast-iron disc, rotating between the two sets of electro-magnets. This cast-iron rotating disc carries sixteen soft iron coils,

passed through the disc. The projecting ends of each coil are wound with wire; thus they form 32 armature electro-magnets. These are connected so as to form eight groups of four each, and the current from one of these groups is used to excite the circles of electro-magnets, whilst the remaining seven groups are employed to give the current for external use. By an arrangement of commutators the currents produced can be obtained direct or

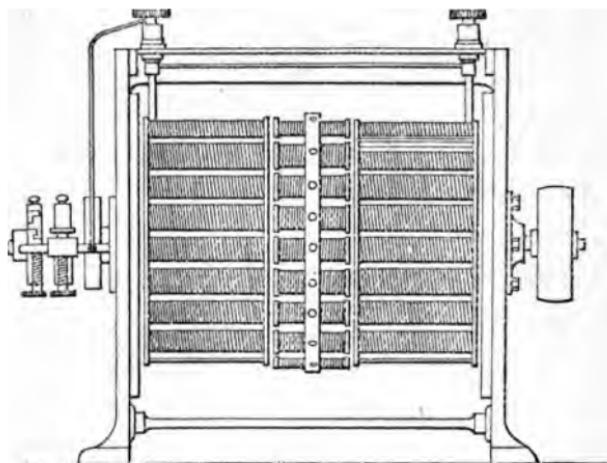


Fig. 53.—Wilde's Dynamo-Electric Machine. Front Elevation.

alternating. This machine is extensively used by the Admiralty in the large ironclads, where it is driven by a Brotherhood engine connected direct to the shaft.

Figs. 53 and 54 exhibit the arrangement of the parts in this new machine.

Rapieff's Machine.

What would appear to be a novel idea is embodied in the specification of M. Rapieff.

He proposes to construct a machine composed of several rings, placed side by side, and revolving every alternate ring, while the remaining ones are fixed. In what way the wire is to be arranged

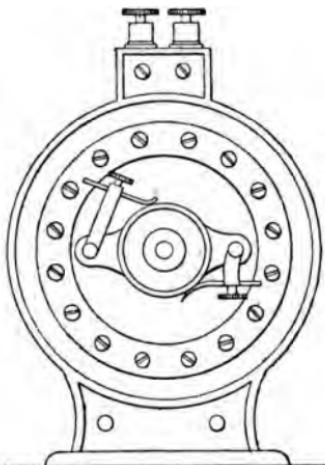


Fig. 54.—Wilde's Dynamo-Electric Machine. End Elevation.

upon these ring magnets and inductors, or in what manner M. Rapieff is to get magnetism into rings for his purpose, is not made clear. The inventor calls these rings two-sided inductors, and it is supposed that an advantage is secured by thus arranging the parts to secure magnetic or electric effect from both sides at once.

The inventor speaks also of the induction of

currents being generally produced in dynamo-induction machines by means of setting some armatures in motion with respect to some inductors, or inversely coiled rings, prisms, or cylinders can be applied to such machines, either as both electro-magnets and armatures, or only as electro-magnets and armatures. The ring-shaped apparatus in which the currents are induced, or armatures, and the inductors or electro-magnets of the same construction through which the currents are sent, can be combined together in several ways; but these various modifications may be considered as arrangements of the construction just spoken of.

As far as the author is aware, the apparatus has not been applied to the production of currents for electric illumination, nor has a public demonstration of the machine's capabilities been made. No particulars as to the way in which the inductors and electro-magnetic rings should be made, or the manner of arranging the coils of wire, are given, so that the author is unable to place before his readers fuller particulars of this machine or the principle on which it is to act.

The Weston Machine.

The makers of an excellent machine for electro-plating purposes—the Weston, of American manufacture—intend to apply it to the generation of currents suitable for the electric light. The machine is well adapted for this purpose, and with suitable

wire upon its armature and magnets will constitute a good generator.

Fig. 55 exhibits the external appearance of this apparatus.

Fig. 56 shows the central arrangement of magnets. There are two sets, the inner, on the shaft, and the outer, fixed to the cast-iron drum. Each set is composed of six magnets. They are

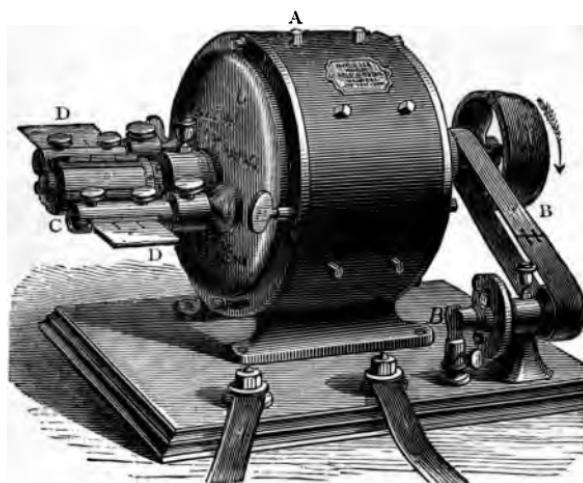


Fig. 55.—Weston's Machine.

arranged in pairs, forming three pairs of horse-shoe magnets. The length, of course, is less for the inside set than for the outside set, which is made fast to the iron drum by screws as shown. These magnets are composed of malleable cast iron, and they have a shape which gives them great inductive strength in little space. It will be seen that, with reference to the outside set of magnets, the

cylinder or drum itself forms the magnetic connecting link between them. The drum being of cast iron, of considerable hardness, always retains, as indeed do the magnets themselves, sufficient residuary magnetism to start the machine in action as soon as the central system is put in motion.



Fig. 56.—Weston's Machine.
Section.

outer set of magnets.

After the currents are generated in the central set constituting the armature, they pass, of course, to the contact brushes, and from these they are at once led into the circuit of the outside set of magnets

by the ends of the wire shown disconnected in Fig. 56. This can be done because the outside system circuit is complete, the wire being wound, without break, over each bobbin in succession. One contact brush is joined to one end of the outer magnet circuit, and the other is connected to one end of the external resistance, the second end of which is connected to the remaining end of the magnet portion of



Fig. 57.
Weston's
Commutator.

the circuit. The contact brushes are shown at D D, Fig. 55.

Much care is taken so to adjust and turn up the faces of the two sets of magnets that they may pass each other as near as possible without actually touching.

The polarity of the armature system is continually being changed when the machine is in motion, because the outside magnets always have like polarity, and by induction change the poles of the inner system six times in one revolution. The inner system should always, in these machines, be of the softest and finest iron, because the changes of magnetic polarity are exceedingly rapid, and much heating, with loss of current and power, must result in the employment of cast or hard iron.

Six impulses are given off at each revolution, and as these are in alternate directions, they are converted into three direct impulses by the commutator. Because these currents are not constant in strength throughout each revolution, the speed should be high in employing the machine for electric light.

The idea is specially applicable to the electro-plating vessel. For electro-plating, the machine is provided with an ingenious contrivance by which the reversal of polarity of the magnets, by counter-currents from the vats, is impossible.

Weston's New Machine.—Since the foregoing particulars of the recognised Weston machine were

written, Mr. Ladd, of London, has communicated to the British Association (1879 meeting) a description with illustrations of an entirely new machine, specially for electric light purposes, devised and carried out with much success by Weston.

The general arrangement of the machine is exhibited in Fig. 58, where A A are the magnet coils.

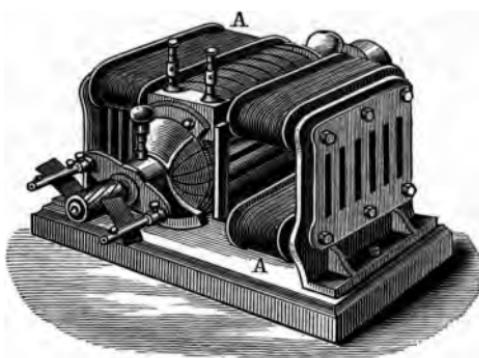


Fig. 58.—Weston's New Machine.

It will be seen that this part of the apparatus is very like Siemens'. The pole pieces, or plates, crossing the armature and embracing it for part of its circumference, are composed of iron plates, placed side by side in a mould, but separated a uniform distance from each other. As the plates are thus set in the mould, the iron magnets on which the wire is to be wound are cast on to "lugs," or projections, on the ends of the plates. The two cast-iron ends and uniting plates form one magnet; the upper and lower magnets are alike,

and when joined together by the perforated vertical supports, the inner curved edges of the field-plates embrace about two-thirds of the circle in which the armature is to revolve.

It will be thus seen that the inventor prefers to employ cast iron and malleable plate in his magnets, making the crossing curved prolongations only from boiler or other rolled plate.

Fig. 59 shows the armature, or revolving portion of the machine. It is built up of plates which are



Fig. 59.—Weston's Armature.

somewhat like a cogged wheel in shape. These plates are stamped out of sheet iron, and when mounted on the shaft are separated from each other at a uniform distance. The radial projections are then arranged in lines, so that the whole forms a very broad cogged wheel, or cylindrical structure, having longitudinal grooves with transverse spaces at regular distances. The longitudinal grooves are for carrying the wire, and it will be observed from the nature of the structure that the wire lies in channels three sides of which are iron, so that the mutual effect upon each other is increased as much as possible.

The ends of the wire are connected to the commutator in much the usual way, the currents

travelling in one direction only to the field magnets. The commutator is fitted on a portion of the shaft which projects beyond the bearings: this admits of its easy removal, and a new one being fitted in a few minutes.

Another important feature in the construction is the arrangement for ventilation; the separation between the pole plates of the field magnets, the perforation in the vertical supports of the magnets, and the light framework of the armature are all for this purpose. The air enters the centre of the armature, and is driven out between the layers of wire through the spaces formed by the separated poles of the armature and field magnets, and thus prevents any part from becoming unduly heated. Machines of this description are made of various sizes and strengths, to give from one to sixteen lights in a single circuit.

This armature should furnish a very good return for the power expended in driving it, but the stamping of its structural parts from sheet iron is a mistake. Sheet iron is always hard, as rolled by the common process, and unless it is very carefully annealed to secure a softer structure, the magnetic poles of such an armature would not change polarity readily from N. to S., or the converse, in revolution. No doubt, however, the thinness of the various parts composing this ingenious armature will greatly aid its performance in practice, and the arrangement of wire is in a certain sense to all appearance superior to

that adopted in the newest form of Siemens' armature.

Trouv 's Machine.

This machine is the result of an idea that a great gain in power would be obtained by doing away entirely with the space necessary in other machines between the moving and the fixed parts. M. Trouv  makes the large inducing magnet

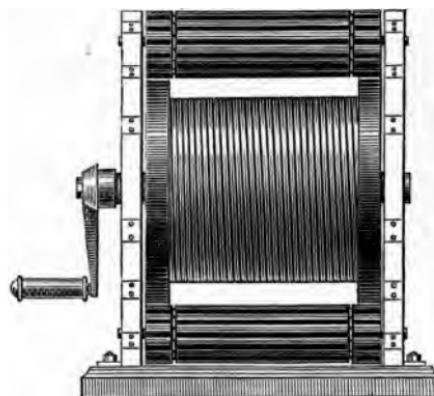


Fig. 60.—Trov 's Machine.

actually touch the cores of the induction coils, and by these means causes the induction coils to revolve also.

Figs. 60 and 61 represent a machine on this principle, where the large central drum is composed of an iron core and ends, wound with wire as usual. This drum-like electro-magnet is surrounded with a frame of spokes at each end, and these frames carry two or more bundles of long, thin induction

coils, which revolve in bearings as shown. This motion is caused by friction between the electro-magnet and the small cores. All the cores approaching the large magnet on one side of their circle have, say, negative currents induced, and those receding from it positive. A commutating arrangement is fixed to the axis of each bundle, and from this the currents are taken off, to be used separately (from each bundle) or in combination with those from other bundles of cores actuated by the same electro-magnet.

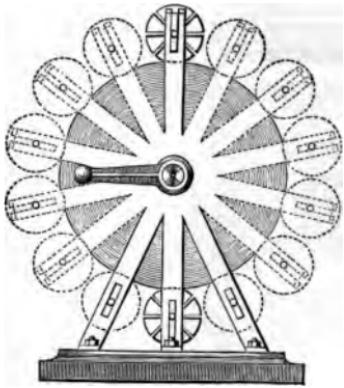


Fig. 61.—Trouv 's Machine. End.

This machine is, without doubt, theoretically good; but it is just as surely a step in the wrong direction when looked at from a practical point of view. The friction of the parts is a very great objection.

tion, and will consume a great deal of power with great disengagement of heat and much wear. The noise is also very great, and the whole apparatus exceedingly complicated, and in large size necessarily costly. If the inventor had struck upon the idea of obtaining actual contact by means of endless steel bands, he would have been nearer the practical solution of this problem. The same principle is applied to a machine similar to the

Gramme, and it is said that this type of machine, which it is not worth the time to describe here, gives a light equal to 600 Carcel burners ; but the power necessary to secure this unlikely light is not given.

Lontin's Machine.

The machines identified with the name of M. Lontin are intended to produce currents in *a number of circuits from one source*. They consist

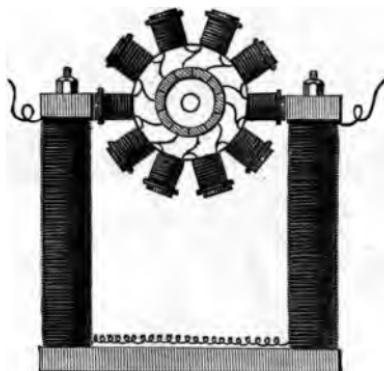


Fig. 62.—Lontin's Exciting Machine.

of a generating or exciting and a distributing machine.

Fig. 62 will give some idea of one of Lontin's first exciting machines, in which several bobbins are arranged on a cylinder and revolve between the poles of the fixed electro-magnets. A commutator is arranged so as to give continuous currents.

The dividing or distributing machine is composed of a series of electro-magnets, M M, Fig. 63,

radiating from a shaft or drum. These electro-magnets are excited by the continuous current from the machine above described, and cause in their rotation induced currents to flow in the coils wound over the soft-iron blocks or cores B B, the circuits being taken from the bobbins B B direct; and those

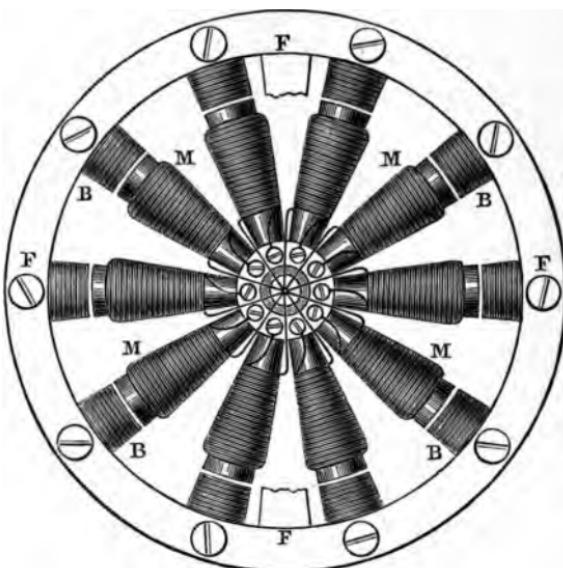


Fig. 63.—Lontin's Distributing Machine.

bobbins may be joined in pairs or otherwise, as may best suit the outside resistance to be worked through. The machine is provided with a keyboard, upon which are fixed the binding screws and switches, to cause the currents to be subdivided to a number of lights. This machine, it will be seen, gives alternating currents.

If there are as many as 10 induction bobbins fixed to the outside frame F F, there will be a possibility of producing 10 lights in as many circuits; or, all those bobbins may be combined to produce one large light, or any number up to 10, as may be required. In this respect the Lontin machine is of much value. It is, in fact, a distributing machine.

In the latest machines of this maker the exciting machines have a number of bobbins upon a drum arranged in diagonal lines, as shown in Figs. 64 and 65, revolving between the fixed electro magnets. By this arrangement the current is maintained more uniform in its strength.

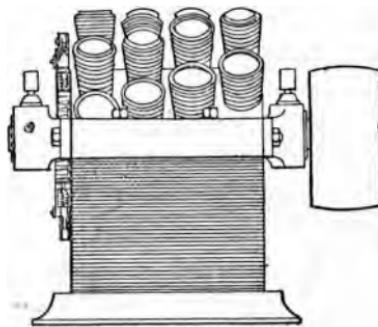


Fig. 64.—Lontin's Exciting Machine.

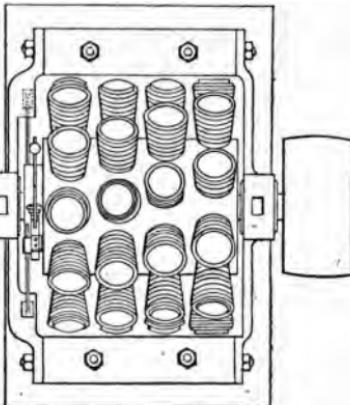


Fig. 65.—Lontin's Exciting Machine. Plan.

Brush's Machine.

This is an American machine, and it may be said that it is an attempt—a skilful one, certainly—to improve upon the well-known armature of M. Gramme.

The armature is a ring with a series of depressions sunk in each side, and in these depressions only the wire is wound. The armature is thus

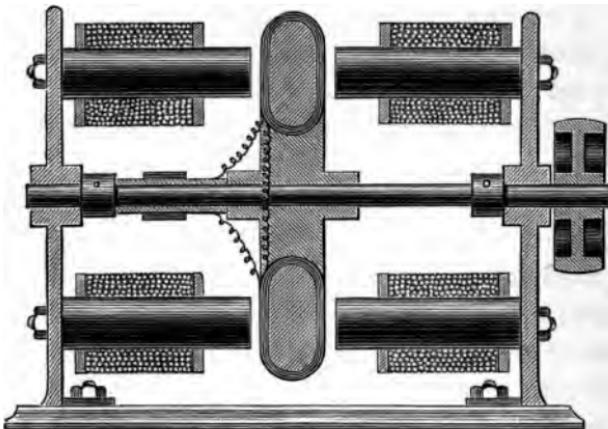


Fig. 66.—Brush's Machine.

only partially covered with the wire coils, and not wholly enveloped, as in Gramme's armature.

Fig. 66 is a longitudinal section representing the way in which the machine is arranged. Two powerful electro-magnets act upon the armature as shown. These electro-magnets are fed from the armature, either by the whole current or by part only, and need not occupy our attention further, since the play of induction is the same as in other machines.

Fig. 67 is intended to represent the armature, coiled with wire. The projecting portions aid greatly in dissipating any heat generated in the coils, with the additional advantage of presenting portions of the armature which may be brought very near to the poles of the magnets, and so take up a greater inductive strain. Concerning this, however, it must not be forgotten, in comparing this armature with the Gramme, that, while Brush gains magnetic effect by nearness to the poles, the armature of the Gramme is entirely covered with wire coils, and that for armatures of the same size the Brush has not so many coils or sections of wire as the Gramme.

In joining up the sections of wire upon the armature, it is usual to connect diametrically opposite sections, by their first and last ends, together, and to carry the remaining ends to two of the insulated contact sections upon the commutator drum. These contact sections should be diametrically opposed to each other on the drum.

In this way all the sections are joined up, and the currents are collected, as usual, by a pair of brushes passing upon the drum at opposite sides. The number of contact slips carried by the drum is, of course, less than that upon or in Gramme's drum.



Fig. 67.—Brush's Ring.

It is usual, in constructing the Brush machine, to lay upon the electro-magnets, before the main stout coils are put on, a layer or two of fine wire. The ends of these layers are arranged so that both electro-magnets are in one circuit of fine wire, and through this wire, when the machine is running, but doing no work, or when it is at work, a portion of the current induced is passing. This idea was adopted by Mr. Brush so that the magnets might always be maintained in a magnetic condition, and is especially useful when the machine is used in electro-plating, the risk of reversal of polarity being great. Weston's idea is even better.

At the competitive trial brought about by the Franklin Institute, United States, the Brush was compared with the Gramme. The Brush machine (small), at 1,400 revolutions per minute, with 3·76 horse-power, gave a light of 900 standard candles, while the Gramme, at 800 revolutions per minute, with 1·84 horse-power, gave a light of 705 candles. It must be considered by all really practical men that there is nothing here in favour of the Brush.

The Wallace-Farmer Machine.

Fig. 68 is a view of this machine. It is of American manufacture, and has been much spoken of as that employed by Mr. Edison, of Menlo Park, in his electric light experiments.

The inducing magnets are flat in shape, and are two in number, attached to the frame. This machine is in reality only an extension of the prin-

ciple upon which Clark arranges his two-bobbin armature, and like it the Wallace-Farmer machine has many defects, due to the way in which the armature is arranged.

Instead of the armature being a straight bar, carrying a pair of bobbins and cores before the magnet poles, two iron discs about an inch apart are employed, studded all round with bobbins and

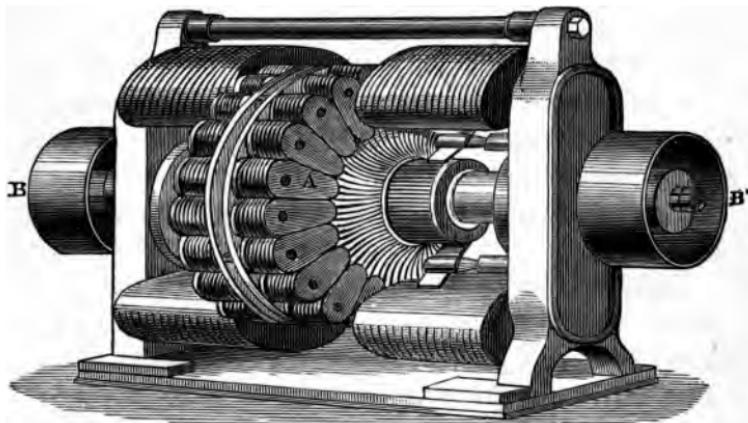


Fig. 68.—Wallace-Farmer Machine.

cores, one set to each disc. The poles of the inducing electro-magnet are thus as far apart from each other as the diameter of the bobbin wheel, or nearly so. There are four brushes and two contact parts upon the axis where the currents are taken off. The bobbins may be coupled up for tension or quantity. The shaft is carried through, and runs in bearings in, the side uprights.

The impulses given off by each bobbin are of

necessity of very short duration, but as the speed is high, these combine to give rise to a fairly continuous current. The construction presents a large surface to the cooling effects of the air, but this also introduces a disadvantage, as the various parts act as a fan, which causes the air to act an appreciable part in consuming the driving power necessary. The high speed—800 per minute—causes the armature wheel to give out a humming sound when in motion, proving the fan-like action of the bobbins.

Heat is developed in such quantity that, despite the cooling by air, sealing-wax may be melted upon the armature wheel when the machine has been some time at work. This temperature is never attained in the machines of Gramme or Siemens.

Variously different arrangements of the magnets, connections, and commutators may be made in this machine. The practice, however, is to oppose to each other the poles of the magnets, so that the poles of the bobbin cores change polarity during every half-revolution. Connecting up is done by passing the currents from the coils, after they have been commuted to one direction, through the inducing magnets, as in other forms of dynamo-electric machine. The collecting points are arranged similarly to those in Gramme's machine, the wires being connected to metallic sectors insulated from each other. Appended are some useful particulars of the wires employed and the work done. The machine is made in two sizes:—

	Copper Wire on Armature.	Copper Wire on Magnets.
Large Wallace.	0·42 in.	50 lbs.
Small ,"	0·43 ,"	19 ,"

Work.—The weight of the large Wallace machine is 600 lbs., of the smaller size 350 lbs. The armatures or bobbin wheels revolve, 800 revolutions in the large per minute, and 1,000 revolutions in the small machine. The horse-power required is, for the large $4\frac{1}{2}$, and $3\frac{1}{2}$ for the small machine. The illuminating power, in standard candles, is, for the large machine, 823, and for the small, 440. Or, per horse-power, 113 for the smaller machine, that given by the large machine not having been determined.

Figures concerning the consumption of carbon by these machines are given by the committee appointed by the Franklin Institute to test them, but they are really of little value, since one quality of carbon is known to burn as fast again as another. The diameter of carbon rods used for the larger machine was $\frac{3}{8}$ in., and $\frac{1}{4}$ in. for the smaller.

Edison's Machine.

Some time prior to Mr. T. A. Edison's discoveries and inventions relating to telephones and phonographs, there appeared in the scientific press a notice of a new idea in electro-motors suggested or worked out by the above able electrician. This thing was called a "harmonic engine," but for what reason it is difficult to conjecture.

A tuning-fork with legs as long as three feet was provided. It was massive and heavy, and was secured by bolts by the bend to a firm base. This fork would, of course, vibrate to a distance of about $\frac{1}{8}$ in. from the centre when struck. Mr. Edison's idea was to keep it vibrating by means of a pair of electro-magnets of small size, with very little current indeed, and to employ the vibratory motions in working a pair of extremely small water-pumps, or at other work.

The whole matter seems to be a mistake, for the vibrations of a fork in no way aid levers to overcome mechanical resistances; nor does it appear to be advantageous to turn electro-magnetic power into vibratory movements in a large mass of metal before applying the power to the work, which would obviously be best done direct.

The author has gone thus far in explaining an idea which is doubtlessly the parent of a machine which has been called Edison's "dynamo-electric machine." In this generator the large fork is also employed, as also the small electro-magnets, in duplicate; also a pair of permanent magnets to induce currents in the electro-magnets. It is proposed to make the great fork vibrate, either by crank and steam-power, or by means of gas or air engines or cylinders connected to the legs direct, which latter device appears to be preferred by the inventor.

It is stated that the length of the legs in a fork for a practicable machine should be about 2 yards,

or 6 feet. It would appear to the author, when it is remembered that such a fork will vibrate only once at least in two seconds, that this machine would utterly fail to produce currents of any value for the purposes of electric illumination.

CHAPTER VII.

GENERAL OBSERVATIONS ON MACHINES.

MEASUREMENT has been made by Dr. J. Hopkinson and by Mr. L. Schwendler, independently, of the energy obtained in the form of current from a Siemens machine as compared with the energy shown to be consumed in driving it, and the result showed that only from 12 to 13 per cent. of the energy is wasted, but as lamps are usually adjusted, only half the energy of the current appears in the arc, or 44 per cent. of the energy transmitted by the strap.

Work to Expect of Machines.

Many machines churn the air to such an extent that a continuous humming noise is produced, and from 1 to 25 per cent. of the total driving power is thus expended upon the air alone. One machine examined wasted 17 per cent., and it is probable that such types of generators would heat to an inconvenient extent were it not for this air-churning.

With regard to the amount of light produced per horse-power this varies considerably in different machines. Experiments were made at the

South Foreland by the Engineer to the Trinity Board, the results of which are given in Mr. Douglas's paper read at the Institution of Civil Engineers in March, 1879. The following are a few of the results obtained.

Machine.	Light produced per H.P. in standard candles, mean of experiments.				
Holmes's Magneto-Electric	475
Alliance	543
Gramme, No. 1	758
", No. 2	758
Siemens' Large	911
", Small	954
", Small	1,254

Thus it will be seen that a good machine should give about 1,000 or 1,200 standard candles per horse-power; but the measurement of the light is, in fact, rather a difficult and doubtful matter, owing to the errors caused by the varying position of the carbon points.

Some of the machines will give over this, and some under; but when the light falls much below 700 candle-power for each horse-power required, it is reasonable to judge the machine as inferior. It will be understood that this is the light ordinarily obtainable from separated carbons in the Serrin or other equally good voltaic arc lamp.

So high an illuminating power will not, in all probability, be obtainable from any lamp of the incandescent type, although incandescent lamps may be found more serviceable on account of steadiness.

Management of Machines.

Skill or knowledge of electrical apparatus is not necessary on the part of the intelligent workman to be employed upon the care of a dynamo-electric machine.

Having obtained a machine, the first consideration should be its fixing. A dry place should, if possible, be selected, and the machine should be so fixed to a firm raised framework of wood that its commutating brushes may be at least 3 ft. above the floor level. The speed to be given to it must then be considered, and such a pulley employed as will produce, at the normal speed of the shafting or engine, the normal speed stated as applicable to the machine with full current. Broad, stout, and well-stretched belts should be employed, and powdered resin employed upon them if there is slipping with ordinary tightness. It is of no use to test these questions while the circuit of the machine is *open*—the machine must be connected by stout wires either to its lamp or to a coil of fine iron wire, measuring, say, from 20 to 200 ft., according to the resistance of the machine. When a suitable resistance is fixed upon, *start the machine with open circuit*, and when the full speed is attained, close the circuit through the resistance, either by inserting the conductor end in the binding-screw, or by screwing up a previously disengaged contact brush.

Now is the time to test the speed, and for this

purpose one of the small speed indicators now used will be found very useful. An engine may run 100 revolutions with the machine at open circuit, and this may fall to 70 on closing the circuit. If there be so great a fall as this, the engine governor is defective. It will, of course, be necessary to open or close the throttle valve upon the governor, until the machine gives, with closed circuit, the proper number of revolutions per minute.

It must be distinctly understood that a dynamo-electric machine will give *less* than its maximum current if the outside resistance, in wire or lamp, is not proportionate to the internal wire resistance of the machine—that is, if the outside resistance is too great, the current set up around the magnets will be small, owing to the resistance, and the machine can only, in such a circuit, produce a small current. If the outside resistance is small—that is, if large short conductors are used, with a proper lamp, the machine will not only give maximum current, but must be controlled by the engine, for upon increasing the speed too much the machine will heat.

Again, *never place the machine at full speed on short circuit*. This is of much importance. If the circuit between the binding screws be closed by a short and stout wire only, all the current will be dissipated as heat *in the machine itself*, and the result will probably be to destroy the machine by burning the insulating covering of the wire. Never, then, allow an inexperienced person to experiment

with the machine. Always see that the outside circuit gives some work to do outside the machine. If there is work to do, a light to produce, metal to electrically deposit, water to decompose, electric motor to drive, or large magnets to magnetise, or resistance to overcome in a long, thin wire, *the machine will be kept cool*, and with very high resistance the speed may even be increased.

All the electric light machines now constructed—Siemens, Gramme, Wilde, Ladd, Weston, Wallace-Farmer, and several others described in this work—have internal resistances of wire, suited to the production of one powerful light with any of the good lamps mentioned, such as the trustworthy Serrin as an example. This resistance will suit them, with as much as 100 feet or over of stout conducting cable, to carry the current to the lamp.

Cables or conductors may be composed of a No. 8 copper wire, insulated with gutta-percha and tarred hemp, or paraffined cotton only—solid paraffin, melted; but it is usually more convenient to make use of a more flexible conductor, composed of from 4 to 8 No. 16 wires twisted together, and covered with gutta-percha and tarred hemp. If the distance between the machine and lamp is over 50 feet, the thickest conductor should be used, so as to reduce the resistance; and if the distance be small, a smaller conductor will serve. These cables are now obtainable of dealers in electrical machines. Their price varies from 2d. to 6d. per yard, according to the size and covering.

Two conductors are necessary in almost every case. Before fixing the ends in the screws of the lamp and machine, see that the covering is scraped off, and then screw down fast. Before starting, either keep one of the conductors out of its screw, or unscrew one of the brushes. Then turn on steam, and as soon as the motion is up close the circuit. The lamp will then at once show light, and will separate its carbons to the proper distance ; nothing further should be necessary, and the lamp should burn steadily until the carbons are consumed.

If there is jumping or flickering of the light the carbons are bad, or this may be caused by the engine not having a sufficiently sensitive governor to keep up a steady motion. If the carbons are bad, there is more need for a sensitive governor, and the engine, however good, will not keep up a steady current.

Dynamo-electric machines, when working upon a voltaic arc lamp circuit, vary much in the strain they put upon the engine. This variation is mostly due to the difference in resistance presented every moment by the carbons of the lamp. If the engine is not provided with a heavy fly-wheel or a sensitive governor, *always employ one of greater power than is really needed*. Thus, speaking of common engines—perhaps of the agricultural type—if 2 horse-power is necessary for the machine, use a $3\frac{1}{2}$ or 5 horse-power engine ; and if another fly-wheel can be fixed to the opposite end of the shaft, let it be done ; also

keep the governor well oiled, to give freedom to its motions.

In the case of driving off shafting, the main look-out is the provision of steadiness in the machine's motion. Large mill shafting, when the revolutions are quite regular, will be found to work dynamo-electric machines to perfection, as will also a large engine of any kind. It will be seen from this that the dynamo-electric machine *needs steadiness in driving if a steady light be required*. Brotherhood's direct-acting 3-cylinder engine is applicable and very suitable.

Gas engines answer fairly well, but they should always be of large size. Otto and Crossley's 8 horse-power gas-engine is probably the best in the market, and is practically as handy in every way as the best steam-engine, but more expensive in working. An engine of the above power will drive two of the small Gramme or Siemens machines steadily, as will also a steam-engine of similar power. Two machines may be driven *off one pulley* by using two belts, one above the other, the machines being placed at different distances from the engine and in a line with the driving pulley. The author has steadily driven three of Siemens' small machines (1,200 candle-power each) from one engine of the agricultural class of 10 horse-power. An additional fly-wheel had to be put on; two machines were worked off one of the wheels, and the third off the other. The motion was quite steady enough for all practical pur-

poses, and three of Serrin's lamps were kept steadily burning.

Water motors of the small type are at present, at least in towns, much too expensive.

Turbines and water-wheels of different kinds are perfectly applicable to the driving of dynamo-electric machines, and where there is a good supply of water at no cost, the expense of illumination in this case would not reach 25 per cent. of that of gas or oil illumination, necessarily of inferior quality. This is reckoning the wages of an attendant, and expense of carbons by the lamp system.

Oil and Lubricating.—For dynamo-electric machines sperm oil only should be used. Every machine should have upon each bearing a "needle" lubricator—that is, a bottle of oil, with a wire working loosely through a hole in its wooden cork. The motion of the "needle," rubbing upon the shaft, liberates the oil as long as the machine runs.

Heating of Machine in Work.—If a dynamo-electric machine should heat to any inconvenient degree within the first two hours of working, there is something wrong either within the machine or in the lamp. If the lamp is adjustable as to distance of carbons, it will be well to increase the length of the arc, which will reduce the heating. A machine that heats much is not properly constructed, and may be improved by taking a layer of wire off the electro-magnet. If the heat rises so high—very near to the electro-magnet, or upon

its body—as to melt sealing-wax, it will be wise to stop working and to increase the outside resistance; and if it should heat with the ordinary external resistance in circuit, the machine should be condemned. A machine *should*, however, heat very rapidly when upon short circuit; if it does not, it is not of much value in the production of light. Care must be taken that the insulation be not injured in an experiment of this kind.

Steadiness may be tested in various ways. Perhaps the most generally applicable test is a Bell telephone. Pass the current, at full speed of machine, through about 500 feet of cable, or 100 feet of stout iron wire. Cut 5 feet of insulated wire, and bind it to the main wire by a cord, fastening its ends on the screws of a Bell telephone. Currents corresponding to the impulses (if any) given off by the machine will thus circulate, *by induction*, through the telephone coil. By placing the ear to the telephone mouthpiece, any augmentation or reduction of working power may be noted by the noise in the telephone becoming greater or less; and if the machine does not give a steady current, the fact will at once be noted. Sudden rushes, ending in a slower succession of impulses—as whir-r-r-r, whir-r-r—will, in all probability, be due to want of sensibility in the driving-engine's governor. With a constant resistance the current should be almost perfectly steady. If there be an unsteady light with a steady current, it will be due to a fault in the lamp, or

more probably to bad carbons, or both. The light should slightly increase in brilliancy as the carbons become shorter, in the case of rod carbons like those used in the Serrin lamp.

Commutators, or Contact Brushes.—Almost every machine has a pair of contact or collecting brushes, to connect the armature wires through the electro-magnet wires to the external part of the circuit, as in the Siemens machine, where the brushes are connected to two ends of the electro-magnet wires. At the other two ends of the magnet wires are the terminals for connecting the external resistance to the machine. Or it may be, in some constructions, that there are 4 brushes pressing upon the collecting axis—2 for the outside circuit and 2 for the electro-magnets.

But contact brushes, for whatever specific purpose, are the same in all machines, although their shape and the material may be different. As far as experience has indicated, the best brush in use would appear to be a copper one; it is generally composed either of sheet or wire copper. The sheet employed is cut into thin narrow slips, and as the material is thin, a bundle of from 10 to 50 is employed. Such brushes press upon the collecting drum in a slanting position, and all the free ends of the bundle are arranged in a slant, or to form an angle of about 20 deg. with the brushes' plane.

Copper-wire so used is rendered hard by repeated drawing, and the bundle is placed in most cases

with the ends equal, and right under or above the axis or at the sides, to right and left, as may be required.

The object of all collecting arrangements is to take off the currents just at the point where there is least sparking, and also to do this with little pressure, because heavy pressure causes much wear and tear of the drum. When commutators and brush-holders are adjustable round the collecting drum, care must be taken to so fix them that the loss by sparking is reduced to its minimum, and when this spot is found, the points of strongest discharge will also be under the brushes. To adjust the brushes, set the machine in motion, and make one just touch the axis, then screw up the other until a moderate pressure is given, and the sparking is very little. Adjust then the opposite one in the same way; but one brush will be found to set off a greater number of sparks than the other. What is really wanted is *the minimum of pressure with the minimum of sparking*. Use common oil, free from grit, upon the commutating drum. Shift the brushes when they become worn or burnt.

Regulators of Current.

Many attempts have been made to invent or introduce some device by means of which currents from dynamo-electric machines might be automatically regulated or governed, as the steam supply is in steam-engines.

There is much use for such an addition to existing generating machines, and a considerable advance towards the general applicability of electric lights will have been made when an efficient regulator has been introduced. For example, the electric light without a steady current is very unsteady, and as constant strength of current depends in a great degree upon the motor itself, it is found that common steam-engines, unless of greater power than is really required, are not the best for the working of electric-light machines. Now there is a want of perfection at three points concerned in the production of an electric light. The engine seldom has a sufficiently sensitive governor; the lamp is at present unsteady on account of various defects in the carbons; and the machine itself is entirely without a means of regulating its supply of current to the needs of the outside circuit.

These faults combined have done much to render the introduction of electric illumination difficult where a perfectly steady source of light is required. Staite and Edwards patented, so long ago as 1855, an electric regulator based upon the heating and expansion of metals by the current to be regulated. The metal used was platinum, in the form of wire; this was attached to a lever amplifying its movements, and the lever in turn moved a resisting coil of wire. This coil was a common naked helix, having some spring, and the action depended upon more or less turns of the wire being pressed together, so diminishing the resistance or

augmenting it as the expansion and contraction of the platinum wire demanded. This idea, beautiful in itself, is really the origin of the regulators used to-day, and the selfsame principle is employed by Mr. Edison, in his attempts to construct a self-regulating lamp. This device is, however, to a great extent a failure from various causes considered under the description given of the lamp.

Dr. Siemens has constructed a regulator worked by the expansion and contraction of a strip of

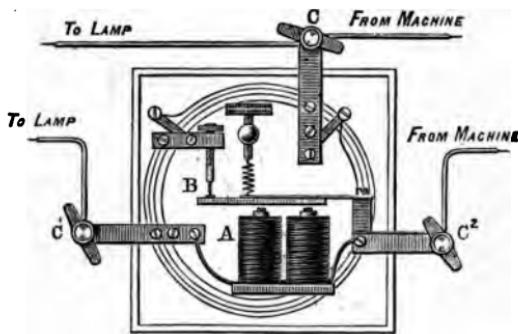


Fig. 69.—Siemens' Circuit "Regulator."

platinum; but the apparatus, so far, has not been practically applied. The action is the same as that employed in Messrs. Staite and Edwards' device. The resistance coils used are put in or out of circuit by the amplified movements of a lever.

Fig. 69 is a view of the working parts of perhaps the best regulator yet put into use generally. It is issued by the makers of the Siemens machine.

A is an electro-magnet in the circuit of the machine and lamp; B is a contact point in connection with the main circuit through the resistance coil shown only. Normally, the electro-magnet attracts the armature and the current passes right through the instrument without resistance; but should the lamp by any accident go out or break circuit, the machine cannot be damaged by the engine racing when the load is taken off. The resistance coil is equivalent to that of the lamp when burning, and to keep it cool it is immersed in a small tank of water in the base of the regulator.

It will at once be seen that this is far from being a regulator, in the true sense of the word, because it is only useful in the case of any *excessive* change in the current strength. It is, however, no doubt a valuable adjunct to the dynamo-electric machine, as much harm cannot be done to either engine or machine when this is in circuit. It is joined up in the usual way, by cutting the conductor near to the machine, and connecting one end to C, and the other to the same point, but, of course, on the opposite side of C, so that when the machine is working the current may pass direct to the lamp. The other connections, C¹ and C², are made by cutting the remaining conductor, and joining up as shown. The instrument may be regulated for strong and weak currents by the antagonistic spring screw and by the contact screw.

In all regulating apparatus intended to regulate

the current by actual breaking of the circuit, a very great objection is introduced by the charge sparking at the contact. A word of explanation as to what this really is will not be unnecessary to the untrained worker.

When two *short* wires are attached to any electric source, their ends touched and then separated, an exceedingly feeble spark only is noted; but when the wires are *long*, a large spark of great brilliancy is produced, and when the same wires are coiled up, especially around iron, the spark is still further increased in size and length. This is usually spoken of as the "extra" current spark, and is due to electro-magnetic induction.

Any regulator, then, depending upon actual breaking of circuit for its action, must so far be a failure, because no contact points yet discovered or tried will withstand the burning power of the electric spark. Edison's lamp was to work by the constant making and breaking of the circuit, and as no contact points could stand this for over a few minutes and retain their sensibility, the idea was thoroughly impracticable, and is only of use in the case of Siemens' check just illustrated.

Dr. Siemens also described, in January, 1879, a regulator based upon the curious property, discovered by Hughes and Edison, that carbon when under pressure will conduct better than when free from pressure. Thus Siemens proposed to place a number of carbon discs in an insulating tube, pass the current through them, and by means of a

variable expansion of platinum, as in Staite and Edwards' apparatus, to vary, by more or less pressure, the conductivity of the carbon series. There is no positive break here, and something remains to be done with the idea.

CHAPTER VIII.

ELECTRIC LAMPS AND CANDLES.

AN electric lamp is the apparatus at which the electric current is actually converted into light. Generally it consists of an arrangement of two carbons for forming the electric arc between them, but endeavours have also been made to obtain light by the mere heating of a short piece of carbon or metal, and in that case the lamp consists of an arrangement for this purpose.

When two pointed sticks of carbon attached to the two poles of a source of electricity, such as any of those previously described, are touched together, a current will pass, and the carbons may then be separated a certain distance without interrupting the current, which is carried on by the intermediate air heated by the current, and an exceedingly brilliant light, which is termed the voltaic arc, will be produced between the carbons.

Particles of burning carbon are projected from one carbon to the other and a portion of the light is attributed to this flow of burning matter, but the greater portion is due to a conversion of electric current into light, as inexplicable as that pro-

duced in a spark discharge between two conductors, or in a flash of lightning.

The positive carbon, or that *from* which the current comes, is consumed very fast, while the negative or receiving carbon is acted upon very slightly, and becomes pointed. Carbon rods will burn at the rate of about 5 in. per hour, according to their size, and as they burn away must be fed up to each other, if it is desired to continue the light. This was formerly done by hand, but now it is done by such perfect automatic lamps that the light is not only perfectly steady, but gives no trouble for several hours together, and needs no attention whatever. It is no difficult matter to feed carbons by hand, by means of a screw attached to one of the pencils, and for taking photographs by quick-acting plates this will answer very well, but a lamp is the only satisfactory means by which ordinary carbon sticks can be burned for general purposes.

In another class of lamps the carbons are kept actually in contact. Thus, if pointed rods of carbon, or one pointed and one flat carbon, are attached to the poles of a source of electricity and the carbons are brought together, a bright light will be produced at the point of actual contact, and will remain practically steady as long as the carbons are kept together. This principle is adopted in several different kinds of holders or lamps. The light is partly due to the incandescence of the carbon and partly to the voltaic arc produced round the point of contact.

Another way is to join the two ends of a powerful current wire by a thin strip or coil of some difficultly fusible metal, or by a strip or thin pencil of carbon itself. In either case the resistance of the material, it being small in bulk, causes the passing energy to heat it to a point past white heat, when it emits a light of considerable brilliancy. The metal generally used in such burners is platinum, sometimes alloyed with other metals, chiefly iridium.

This is called light from incandescence, and there are in use various devices by means of which the principle works perfectly well.

Such lights are not so brilliant as those produced when the carbon pencils are actually separated.

As early as 1843 experimenters were at work upon the useful production of electric lights, and the celebrated Foucault produced the light from rods of gas carbon and a battery of Bunsen cells. Previously to this wood carbon was frequently used, and among others by Sir Humphry Davy, at the beginning of the present century, when he produced his (and the first) voltaic arc over the Royal Institution, from a battery of 2,000 cells.

It was soon found that the electric light was not only independent of air or oxygen for support, but possessed the properties of sun-light in showing all colours as they should be seen. It was also found that no vapours, smoke, or appreciable (diffused) heat were given off by it, and that its chief peculiarity was exceeding brilliancy difficult of diffusion.

Fig. 70 is an enlarged view of the carbon points as they actually appear when their image is thrown upon a screen for examination. P is the positive or feeding end, and N the negative or receiving. The nodules observed chiefly on the lower carbon are impurities in the substance, which melt and stick to the points. The light itself is not only produced by electricity itself, but by millions of highly incandescent particles carried from the positive to the negative carbon.

The stronger the current under these conditions the stronger the light, and the greater distance will the carbons admit of being separated without extinguishing the light.

The power of electric lights is usually expressed in terms of standard candle power, and varies from, say, 100 candle power to 16,000, above which it has not as yet been found convenient to go in one light, as carbons are at once split up with higher power.

It would appear that about the year 1845 the first patents were applied for in electric lamps or burners. The names of King and Wright are the first concerned in the invention of patented apparatus of this kind. King's patent was for an incandescent burner of platinum, and Wright used revolving discs of carbon. Probably the best attempt

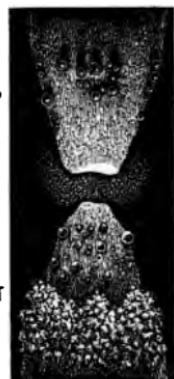


Fig. 70.
Carbon Points.

at obtaining a steady light shortly after this date (1846) was that of Staite and Edwards, who made a lamp in which two rods of carbon were pressed together at an angle upon some badly conducting substance. Greener, Staite, and Petrie then produced lamps of various kinds, and in 1848 a self-regulating lamp was made by Foucault.

It will be unnecessary to give particulars of all the numerous, and often useless, pieces of apparatus invented since 1845; but the author will describe those only which have been well tested by electricians in practice.

Carbons.

As has been before stated, rods of charcoal were first employed as the points in the production of electric light. This burns too fast, and is too easily split, although, when well prepared, it gives a steady light.

The scale of deposit found in the interior of gas retorts after trial was found to be well adapted for the purpose. This substance is cheap enough, as it may usually be obtained for the trouble of carrying away; but it is not, in its crude state, well suited to the production of steady lights. It is very impure, containing various foreign earthy matters, sometimes metals; but silica is the most troublesome constituent, as it is more difficult of fusion than the pure graphite. A good gas carbon is of a fine texture, and a clear grey colour. It is very difficult to cut or shape on account of its hardness.

Many attempts have been made since 1846 to obtain a perfectly pure powder of graphite or other substance suited to the steady production of light.

Staite and Edwards' Carbons.—These were in use for a considerable time before other inventors came into the field. They were made by finely powdering the best gas carbon, mixing with a little sugar syrup, kneading and compressing in the shape of rods. They are then gently heated and saturated with a strong solution of sugar, when they are heated to whiteness, and are found to burn with tolerable uniformity in good lamps. The same method, with the substitution of tar for the syrup and the addition of ground charcoal, was patented by Le Molt a few years later.

Archereau's Method consists of mixing with the ground and selected graphite some magnesia, which is supposed to render the light more steady.

Carrel's Carbons.—These are, and indeed have been, the standard carbon rods in use. He mixes with the substance certain proportions of potash and soda, which slightly lengthen the arc and add to its brilliancy. Good carbons are made from the powdered carbon, lamp black, and syrup of cane-sugar, with a little gum. The proportions may vary, but the following are recommended:—Carbon powder, 15 parts; calcined lamp black, 5; syrup, 7. These substances are perfectly mixed, with a very little water added, when the mass is well pressed and rounded by being passed through a draw-plate. They are then baked dry,

and while still hot are put into a solution of cane sugar or a strong syrup, which is pressed into their pores, and they are then again heated to a high temperature. Carré would appear to prefer coke dust, as found in retorts, to ground carbon.

Many attempts have been made to improve the conducting power and steadiness of carbons by coating with metals. They are almost all failures, and lamps are now in use by which the current is not caused to travel the whole length of the carbon. A great many mixtures have been tried both inside and outside the carbons.

Carbon rods frequently crack and split at the points, putting out the light for an instant. This usually results from the use of inferior carbons, and by employing them of too small a body for the current. Carbons should be selected to suit the current to be passed through them. If they are irregular in composition they will crack, and whether regular or not they will crack when the current is too strong for their size. M. Gramme mixes with the powders nitrate of bismuth, which is of use in preventing cracking and augmenting the steadiness and power of the light. The average price charged for good carbon rod, $\frac{1}{8}$ -in. in diameter, is 10d. per foot.

Lamps with Automatic Regulators for Arc.

When the electric light is obtained by carbons separated a certain distance so as to produce the voltaic arc the carbons consume away, and thus

increase the length and electric resistance of the column of heated air between them. As the resistance increases, the current of course decreases; this decrease of current again lessens the heat of the column of air which has already been lengthened, thus the rapid increase of resistance soon causes the arc to cease altogether suddenly. To overcome this the carbons must be kept constantly at the same distance apart. At first this was done by hand adjustment, but this was evidently an incomplete arrangement, and the attention of electricians was turned towards some means of overcoming the difficulty by mechanism that should act automatically.

In 1846 Staite used clockwork to bring the carbons together, the rate of the clock being previously regulated to suit approximately the consumption of the carbons, but this was not found to answer, as the carbons burn irregularly.

Attempts to make the decrease of current itself adjust the carbons were soon made. It is difficult to give the date of the earliest invention for this purpose, but Staite as early as 1847 patented a lamp in which the clockwork for moving the lower carbon is controlled by a movable weighted soft iron core acted on by a hollow electro-magnet.

Perhaps the Foucault and Wilson lamps were amongst the earliest. But the author cannot pretend to place the various lamps in chronological order, but commences with the Serrin lamp, as a good type of the clockwork or self-regulating kind.

The Serrin Lamp.

This lamp is, in all probability, one of the best contrivances of the mechanical kind ever constructed for the perfect regulation of the electric light, as produced between a pair of vertical rods, end to end. It is in more extensive use than any other lamp of the kind, and experience has shown that there is really no better automatic lamp in existence for producing the light by this particular method. Serrin's lamp, as made by M. Breguet, is used in the lighthouses, and for almost every electric light of the single kind yet established. Its price is high, £21, but a glance at its construction and efficiency in use places it far before others at lower prices.

Fig. 71 is an illustration of the interior of this lamp. A is an electro-magnet; B its armature, which, when the current passes, is attracted, and through its connection with the sliding bar of the lower carbon, E, pulls it down, and makes the separation. The apparatus is put in motion, not by a spring, but by the weight of the upper carbon holder constantly tending downwards, which pressure communicates motion to the train of wheels by its toothed rack, as shown. The rate of descent in the upper carbon with its rack is, of course, regulated by its setting the wheel train in motion, which brings a check, connected to the left side of the lower carbon holder, to bear upon the arms of the radial fly-wheel lowest in the train

of wheels. This locks the length of the arc until from burning away the current becomes weak, and the armature is allowed to go upwards with its lower carbon holder. This it is enabled to do by the springs constantly pulling it away from the magnet. When the lower carbon can thus move upwards, the upper, its wheel train being free, by the check being taken off the radial fly, falls until the current is strong enough to again pull down the lower holder and to again bring the check to bear upon the radial fly, thus locking the distance. F is an adjusting screw, and the two upper screws are for the same purpose. This lamp gives no

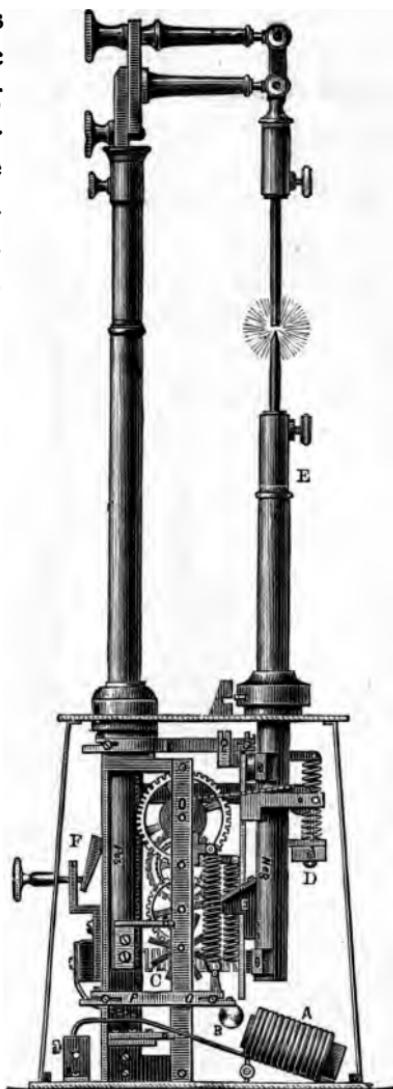


Fig. 71.—Serrin's Lamp.

trouble, and may be set in action by the most ordinary workman. It will take any length of carbon rods up to about 12 inches.

Archereau's Lamp.

Fig. 72 represents the lamp invented by M.

Archereau. It is very simple in construction and action, and forms one of the best regulators for short periods in use.

The author can especially recommend this form of lamp to the notice of amateurs, or those requiring a simple regulator, easily made and managed for short

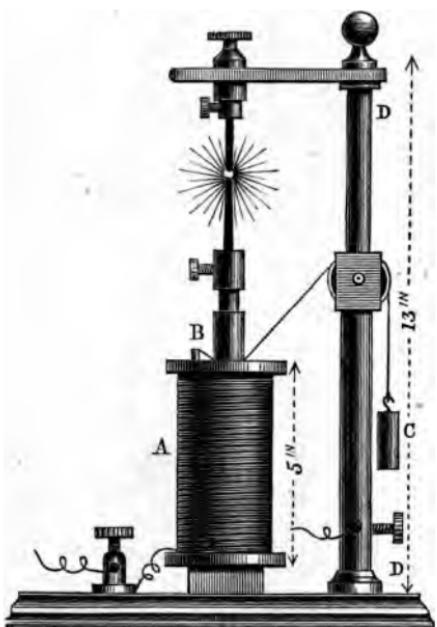


Fig. 72.—Archereau's Lamp.

periods. It will be found very well suited for the production of electric light in magic-lantern and other similar apparatus, while it is also suitable for larger displays or the illumination of buildings.

It consists of a bobbin of No. 12 silk-covered wire, providing one layer, or two at most, for

weak currents, A; having within it a column of metal, B. This is best made of one half (top) copper, and the other half (bottom) of soft iron. The upper end, B, carries the lower carbon rod, which is fastened in its end by the set screw shown. The connection to this coil of wire is from the binding-screw to one end, while the other end of the coil has soldered to it a thin copper spring pressing gently upon the copper part of the interior column. The current thus passes to the lower carbon, while the other connection is made to the metallic upright at D. This metallic pillar may be of brass, and it must carry a right angle arm, to which the upper carbon holder is made fast as shown. A counterpoise weight, C, is supported by a cord, which passes over the central pulley, and, going to the inner side of the metallic column in the wire coil, supports it in position, with a gentle pressure between the points.

The connection with the electric source must be so made as to draw down the iron cylinder by the induced magnetism. The action is, then, this: the current passes into the coil, up through the carbons, and at once separates them. If the separation has been too sudden or far, the weight will bring the points nearer to each other again. The arc is established as soon as the current passes, and the weight should so counterbalance the column that its action may not be too strong for the current. It will be found best to have the counterpoise adjustable in weight.

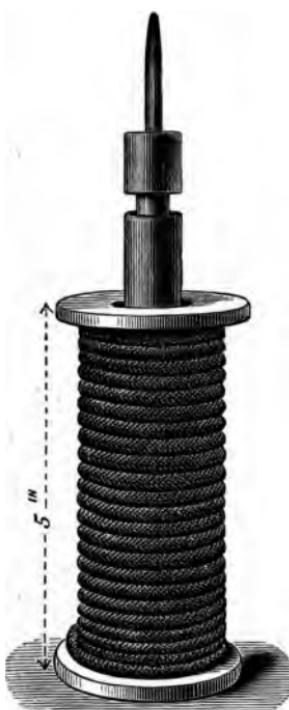
Fig. 73 represents a coil and bobbin of wire for this lamp, having within it the copper and iron column, with the carbon rod fixed in the top. For a lamp to burn, say, for $1\frac{1}{2}$ hours, with a light of

500 candles, the wire may be No. 12, and it should be silk-covered.

The bobbin should be of hard wood, with a thin tube. It may be 5 inches long, and the central hole may be $\frac{3}{4}$ in. in diameter, while the diameter of the sliding column may be $\frac{1}{2}$ in. or even less. The upper portion will do if of copper tube only, and it will be found most convenient to make the lower half of soft-iron bar. The total length of the column may be 7 inches, and it should be provided with a brass or iron socket, having a $\frac{3}{8}$ -in. hole in its end for the reception of carbons of different sizes.

The total height may be 13 inches, and the cord pulley must be placed above the middle portion of the main pillar, as shown, in a slot cast or cut for it. It will be found convenient to have the right-angle arm adjustable around the main pillar as an axis by

Fig. 73.—Bobbin for Archereau's Lamp.



a thumb-screw; and a good plan is to have the top carbon screw or socket drilled right through, so that the carbons may be pushed downwards from the top.

The base must be solid and firm. It will be found best in most cases to provide one of cast iron, and to insulate the binding-screw from it by fastening in a block of wood in a $\frac{1}{2}$ -in. hole cast in the base.

Of carbons, the size will depend altogether upon the strength of current to be used in the production of the light. This lamp is very well suited to the current as obtained from voltaic batteries, and it will prove useful to give sizes of carbons best suited to different strengths of such currents.

A current from 50 'cells of the Bunsen, or 40 of the bichromate of potash cell, will consume from $\frac{1}{2}$ to $\frac{5}{6}$ -in. carbon rods, and if the cells are large the carbons may be ordinary $\frac{3}{8}$ rods; for smaller numbers of cells the $\frac{1}{4}$ -in. rods will be found quite large enough, and round rods are better in work than square. They should be pointed on commencing the light.

Gaiffe's Lamp.

This lamp bears a strong resemblance in principle to the regulator devised by Archereau, previously described.

It has a vertical coil of stout wire (Fig. 74), into which the lower carbon bar, A, is drawn when the current passes. This bar, unlike that used in

Archereau's lamp, is toothed throughout a portion

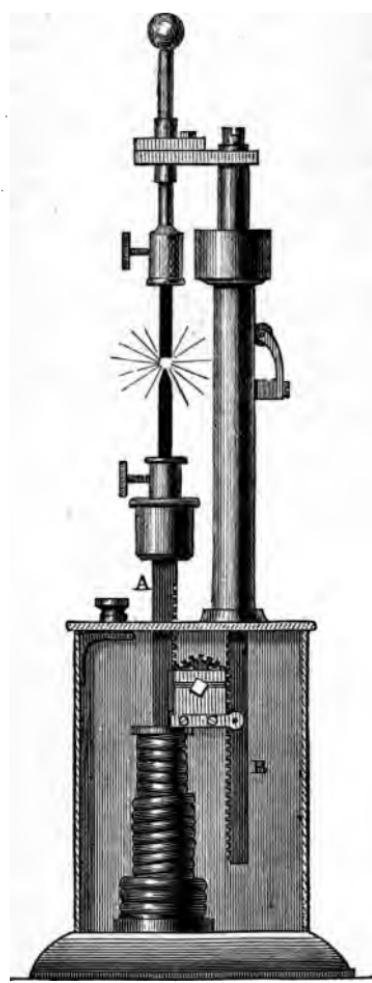


Fig. 74.—Gaiffe's Lamp.

of its length, and actuates a wheel of 25 teeth, the spindle of which carries another wheel of 50 teeth, insulated from the spindle. The second, or largest, wheel engages another racked bar, B, actuating the upper carbon, and any motion of the first bar in its coil gives a rate of approximation of 2:1 to the bars, the upper having, of course, to move the faster to make up for the greater length burnt.

Fig. 75 shows the racks, E and E; F is a pair of wheels bearing the ratio 2:1 to each other's effect upon the racks. The rack actuating

the upper carbon is made to move the faster, because it is consumed so much faster than the lower point.

In order to maintain the contact between the carbons when the current is not passing, a clock-spring is provided upon the spindle of the wheels, and this constantly urges the carbons together. The strength of this spring is such, that the pull of the bobbin upon the lower bar, when the current passes, will overcome it, and separate the carbons to the required distance for the production of a brilliant light.

All the parts of each carbon holder are, of course, insulated from each other. There is a great advantage in this arrangement as applied to such purposes as require the light to occupy one point continually, such as in lighthouse illumination and the working of various instruments, including magic-lanterns. It is a well-constructed and arranged lamp, and on account of its simplicity can be understood at a glance; while the cost of construction and the market price is much lower than that of Serrin's lamp, before spoken of. The lamp may be obtained through English houses at about £8, while the Serrin costs about £21. The Gaiffe lamp is not, however, adapted for the consumption of very large and long carbons. Otherwise it may be said to possess all the advantages claimed for the Serrin, and is certainly more manageable when anything goes wrong in untrained hands. It is fixed upon a steady base, and a circular metallic case encloses the working parts.



Fig. 75.
Lamp Rack.
work.

Duboscq's Lamp.

The regulator connected with the name of Duboscq was invented originally by Foucault, though the mechanism has been considerably improved by Duboscq. This lamp is well known in England, as it was for a long time the only efficient regulator of vertical carbons obtainable. It has had considerable application in the production of electric

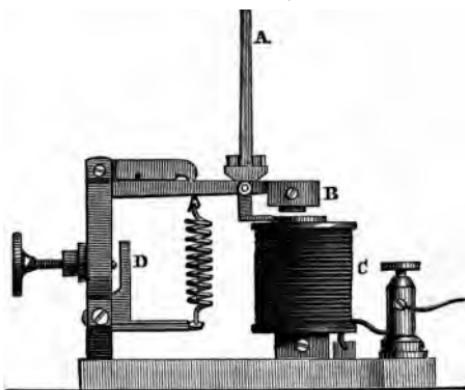


Fig. 76.—Detent of Duboscq's Lamp

tric lights for demonstrating purposes, such as the experiments of lecturers and occasional displays.

It has the same kind of regulating arrangement as Gaiffe's lamp. The racks are, however, in this arrangement actuated entirely by a clockwork spring and train, and the current only performs the part of stopping and releasing this train when the carbons are apt to go too near to each other, or the current is too weak by too great separation of the points.

Fig. 76 exhibits the arrangement adopted for stopping and releasing the train as required. A is a metallic finger or detent, which stops or releases the mechanism contained in a case above. B is a soft-iron armature to which the detent is attached; C is an electro-magnet, by which the current is enabled to control the movement of the parts as required. D is an arrangement controlling the spiral spring shown, which balances the attractive force of the magnet when in work.

The current may be said to have almost perfect control over the movements of the points, and permits approximation to each other until the arc or separation for light is of a suitable length for the current to maintain. The arrangement D, acting upon the antagonistic spring, enables the adjustment of the lamp to any given strength of current to be easily made by hand before commencing work. In this lamp also the points are kept as nearly as possible in one position, and for this reason the arrangement is suitable for lighthouse work, but it is undoubtedly inferior to Serrin's and Gaiffe's.

Siemens' Lamp.

This lamp was originally devised by Herr Häfner von Alteneck, who was the inventor of the particular mode of winding the wire on the armature in the Siemens' dynamo-electric machine in its present form.

As in several other lamps, Siemens' apparatus

has the carbon holders racked, and the pinions of the racks are on one axle and of such diameters that the upper carbon has double the run of the lower.

Fig. 77 exhibits the chief peculiarity of this lamp.

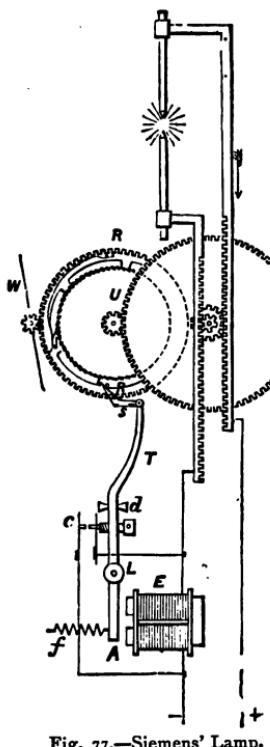


Fig. 77.—Siemens' Lamp.

It will be seen that it consists of an electro-magnet arrangement, A, L, T, through which motion may be communicated to the ratchet wheel, U, by the pawl S. L is the fulcrum of the magnet armature, which is caused to oscillate opposite the poles of the electro-magnet, E, by reason of a contact-breaking arrangement being situated at C, with an adjustable platinum-tipped screw. The armature is pulled from the magnet poles by an antagonistic spring, f. When the spring is enabled, by the cessation of magnetism in the magnet, to pull to itself the armature, the pawl, S, is compelled by a pin to

leave the teeth of the ratchet wheel, U, and the upper rack may then descend, causing, as it does so, the under rack to ascend at half the speed. The current goes, as indicated by the arrow, up one wire and rack and down the other.

This lamp is suited to work either with alternating or direct currents, but if alternating currents are used, there is no need for the contact-breaking stop, C, the change of polarity in the connections giving the required motion.

In the case of a direct current, the action is as follows:—As soon as the current passes, a small light is shown at the point of contact of the carbons, and this passage of current causes the electromagnet to work the armature with an oscillating motion until the pawl has separated the carbons through the rotation of wheel U. When the separation is sufficient the current is weakened, and the antagonistic spring prevents the weakened magnet from giving further motion to the wheel. A continuous check is thus kept upon the falling tendency of the rack with the upper carbon. This lamp is admirably suited for lighthouse and general purposes.

The Siemens and Häfner-Alteneck Pendulum and Differential Lamps.

This lamp, the invention of Herr Häfner von Alteneck, recommends itself at once by the almost total absence of wheels and the simplicity of its moving parts. The lower carbon-holder is in this lamp a fixture, and the upper carbon-holder is formed by a rack, which in sinking down will turn a pinion. In order to moderate the speed with which this pinion turns, a common escapement-wheel with its pendulum is fixed to the same axle.

A movable frame, serving as a guide to the upper carbon-holder, carries the pinion and the pendulum, being lifted, more or less, by a solenoid acting on an iron core connected to the framing. During the normal burning of the lamp, a small lever fixed to the movable frame catches the pendulum, preventing it from moving, and thus keeping the upper carbon-holder stationary. When the arc becomes too large, or the current is weakened by other causes, the solenoid will let the frame drop a certain distance, the free end of the little lever is arrested by a projection of the lamp casing and the pendulum is free to move. The upper carbon will then at once descend, but as soon as the distance between the carbons is diminished, the strength of current will increase, lift the frame, and the little lever will again stop the downward motion of the upper carbon-holder. In order to lessen the suddenness of the motion of the framing, an air-pump is connected with it, and a spiral spring is attached to the core, by which the attractive force of the solenoid can be more or less assisted according to the strength of the current. In practical work this form of lamp has proved to be very efficient, as its management is easily understood, and hardly any part of it can get out of order. Six such lamps have been in use at Blackpool, a watering-place in Lancashire, during two months in all sorts of weather, and never failed after a few mechanical imperfections had been removed. Similar lamps are at work in the British Museum, where all the

apparatus has been managed, after the first fortnight, by the Museum authorities themselves, and no difficulty has been experienced by them in maintaining the regulators in good working order. At present these lamps are being exchanged for others which work on the same principle, but have the case containing the solenoid and the moving frame above the point of light. This modification has been adopted because it facilitates the construction of suitable lanterns, but it does not differ from the form first described in the way of regulating the approach of the carbons.

In the lamps just described, as in most of those of other makers, the strength of current regulates the distance of the carbons, and the consequence is, that it is not possible to connect two or more of them in one circuit. To overcome this difficulty, Mr. v. Alteneck used another principle, which in some respects resembles the pendulum lamp. The upper carbon is attached to a similar rack moving in a slide, and turning a pinion with pendulum attached, but the motion of the movable frame is governed by *two* solenoids instead of one. The frame is attached to a lever, which carries a double iron core reaching into the two solenoids. One of these acts in the same way as the solenoid of the pendulum lamp, separating the carbons whenever a current passes through it. The other one consists of fine wire having a high resistance, and forms a shunt to the main circuit, the ends of the fine wire being connected direct to the terminals of the lamp, and

by attracting its wire it brings the carbons together or releases the pendulum respectively. The action of these solenoids will, therefore, be balanced when the difference of potential on the two sides of the arc is of a certain magnitude, depending on the relative position of the two coils and the resistance of the wire on them. By this arrangement the quantity of the current flowing through the lamp has no influence on the relative position of the carbons, and nothing prevents a large number of them being inserted into one circuit. In producing light by alternate currents as many as 24 of these lamps have been worked in series, and their behaviour was all that could be desired. In order to make these lamps independent of each other a little contact piece is attached to the movable frame, which makes a short circuit from one terminal to the other whenever the frame is in its lowest position.

The principle of the action in this differential lamp is exhibited by Fig. 78, where *g* and *h* indicate the carbons held respectively in the sockets *a* and *b*, and provided with means of feeding as they are consumed. One socket, *a*, is attached to one arm, *c'*, of a lever pivoted at *d*, and having its opposite arm, *c*, connected to a piece of non-magnetic material uniting a pair of iron cores, *s s'*. The core, *s*, is free to play up and down within a solenoid *R*, the coil of which is of large wire offering small resistance, and forms part of the lamp circuit. The core *s'* is free to play up and down within a solenoid *T*, having a coil.

of smaller wire offering a greater resistance than the coil of R. The coil of T is in a circuit external to the lamp, that is to say, joining the conductors L L', excluding the carbons. When the solenoid R, being excited, draws in its core s, the points of the carbons are separated; when on the other hand the solenoid T draws in its core s', the carbons are caused to approach each other. As the relative force of the two solenoids depends upon the strengths of the currents of electricity passing respectively through the coils, and as this depends upon the relative resistance of their respective circuits, the one circuit, consisting of the coil T and its connections to the main circuit of L L', and the other consisting of the coil R, the two carbons and the arc between them, that portion of the latter which consists of the arc being dependent on the distance of the carbons apart, this distance will become adjusted automatically by the action of the two solenoids, so as practically to maintain constant the action of the lamp. If, for example, the carbons should be too near together, a larger proportion of the electric current passing through coil R than

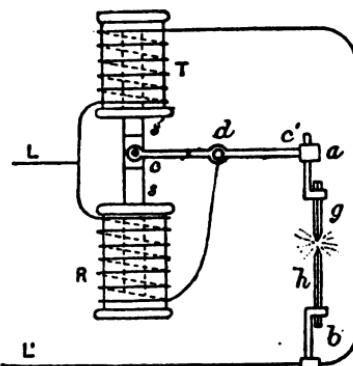


Fig. 78.—Siemens' Differential Lamp.

through coil T will cause the superior attraction of the core s, separating the carbons, and thereby increasing the resistance of the arc between them, and so lessening the quantity of electric current that passes through them. If, on the other hand, the carbons should be too far apart, then the coil R, being less excited than the coil T, will exert less attractive force on its core s, permitting the other core s' to be drawn into its coil, and thus causing an approach of the carbons which will lessen the resistance of the arc between them, and so permit the passage of a larger proportion of the current through them; thus the regulation of the lamp being dependent only on the resistance of its voltaic arc, and independent of the strength of current, the action of any one lamp in a circuit will not affect that of other lamps in the same circuit, and consequently a number of such lamps can, by means of this invention, be effectually worked in one and the same circuit.

Both in the "pendulum" and in the "differential" lamp the lower carbon is fixed, the focus of the light will therefore gradually descend. For some purposes it is, however, necessary to keep the focus in the same place, and Dr. William Siemens has suggested a simple contrivance to attain this end. The lower carbon is enclosed in a tube and, by means of a fine wire, a roller and a weight, is pushed against a screw fixed to the upper end of the tube. As the carbon wastes away by the action of the current fresh carbon is fed upwards by the

weight, and the shape which the carbon assumes admits of the screw being far enough away from the arc to prevent its being injuriously affected by the heat. It is obvious that in such a case much longer carbons can be used, and that the time during which a lamp can remain alight without removal of carbons, is thereby very materially increased.

This "abutment" pole is employed for both electrodes in the last form of lamp invented by Dr. William Siemens, but the screw, against which the carbons are pressed, has been replaced by a knife-edge, which appears to give better results. In this lamp the carbons are placed horizontally, and their tubes are attached to Bell crank-levers, the other ends of which support the core of a solenoid, on which fine wire is wound, forming a high resistance shunt from one terminal to the other. The action of the lamp is very simple; the weight of the core, which can be varied at will, keeps the carbons apart when no current passes. As soon as a current arrives the solenoid will lift the core, the carbons touch for a moment and the arc is established, the further regulation depending again on the difference of potential *only*, and being independent of the *strength* of the current. No wheels whatever enter into the construction of this lamp, and all its parts are exceedingly simple.

Lontin's Lamp.

M. Lontin, inventor of the Lontin dynamo-electric machine, has sought to improve upon the

well-known Serrin lamp by introducing parts for its working of greater simplicity than hitherto.

It would appear that this inventor bases one part of his improvement upon the Serrin lamp upon the expansion of a metallic bar by the passage of the current through it, and by substituting this bar for the electro-magnet employed in Serrin's lamp. Up to the time of going to press, however, no further particulars of this apparatus are obtainable, and it must be as yet considered as under the examination it deserves.

M. Lontin has also invented a form of lamp in which any length of carbon rods may be employed. The lamp and carbons in this invention are horizontally placed, instead of vertically, as in most other lamps. The carbon holders are hollow throughout, so that any required length of rod may be inserted in them.

One of the carbons, as it passes through its support, is moved by a pair of rollers bearing with gentle pressure against it. This rotation is kept up by bevel wheels actuated by a spring and clock movement in the case of the lamp.

There is a disadvantage, however, in placing the carbons horizontally, as they are found to give much less light than vertical ones.

This lamp is not quite new. An invention brought out several years ago employed the tubular holders and the driving by clockwork; and the mechanism was, perhaps, as effective in use as that here spoken of, while the position selected was a

vertical one, which is certainly superior to the horizontal plan, when the light power from a given current is considered.

Carré's Lamp.

The inventor of the Carré induction (high tension) machine has produced a lamp which is judged by some to be an improvement on Serrin's lamp. He employs a double solenoid instead of an electromagnet, which is supplied with an armature of S shape. This armature is caused to oscillate round a spindle, or pivot axis at its centre, and the two ends enter a curved bobbin. When, from any cause, the current is interrupted, this armature is withdrawn by springs as usual, a detent releases the mechanism, and the carbon points come into close contact, so re-establishing the current. As in Serrin's lamp, the mechanism of Carré's device is actuated by the falling weight of the upper carbon holder.

When the current passes, the ends of the armature are sucked into the solenoid, and the carbon points are at once separated to the distance required to produce the voltaic arc.

Girouard's Lamp.

M. Girouard invented the device bearing his name in 1876, so that it is an attempt to improve upon the apparatus previously in use. The apparatus consists, essentially, of two distinct parts :

the lamp itself, with its clockwork mechanism for effecting the regulation of the carbon points, and an instrument intended to act as a relay, or regulator of the current, which is fixed to the lamp. This relay is actuated by the current from a portable voltaic battery. The second or relay part of the lamp controls the mechanism of the lamp proper, and through it the length of the arc; which is, of course, produced by another current obtained from a stronger voltaic battery, or a dynamo-electric machine. The idea in itself is good, but it cannot be said to be well carried out in this lamp.

Brush's Lamp.

This is an American invention, by Mr. Brush, who is also the inventor of the well-known Brush dynamo-electric machine. Like some of the most efficient electrical apparatus in use, its construction is exceedingly simple, and its parts are so arranged as to make it very certain in action as well as prompt to respond instantly to changes of current strength.

Fig. 79 is an illustration of its chief part only. Its under parts, such as the base and lower carbon holder, are constructed like most other lamps. There is no mechanism in the under arrangement of simple base and holder, and the part shown herewith has the action of the lamp entirely under control.

A is a coil of stout insulated wire, consisting

of 2 or more layers. Its interior provides a cylindrical vertical aperture, and the bobbin is fixed upon a supporting plate, as shown.

B is an iron hollow core, fitting easily into the aperture in A. This core is able to move up and down a short distance. Within the core, B, is a brass or iron rod, C, which is also the upper carbon-holder. This rod is loose in the aperture of B. At D is shown a bent finger attached to B, the under end of which is bent and catches underneath a brass washer, D, placed somewhat loosely on the rod, C. This washer is otherwise quite free.

E is a set screw, which is moved by hand. It is intended to control the movements of the

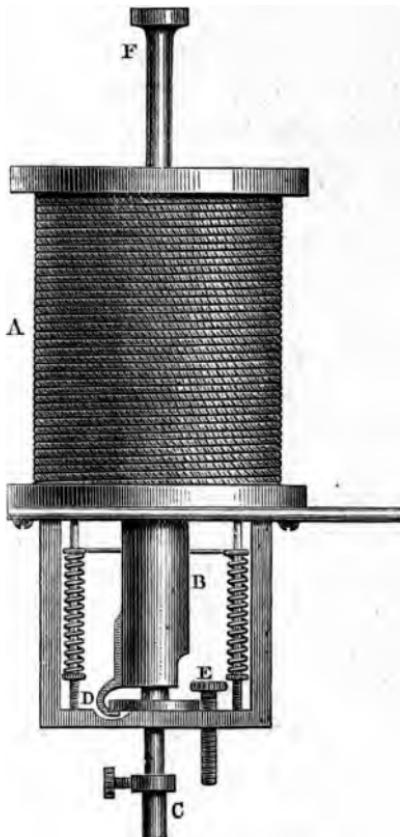


Fig. 79.—Brush's Lamp.

washer, D, by being screwed more or less down upon it.

If one wire from the dynamo-electric machine or battery is connected to the lower carbon, while the other is connected to the commencing end of the wire coil, A, the finishing end of which communicates with the upper carbon-holder, the current will pass from the lower carbon through the upper as fastened at C, through the wire coil, and the circuit is complete. The core cylinder, B, is then, by the force of the magnetism created, drawn up into the interior of A. By means of the lifting finger, D, it raises that edge of the washer, until, by the washer's angular pressure upon it, it lifts this rod upwards, and will raise it to such a height as may be determined by the height of the thumb-screw, E. As long, then, as the magnetism remains the same, the rod C, with its upper carbon, will remain fixed. While the current is not passing, the rod, C, is quite free to descend until its carbon point is supported by the lower carbon. This is the condition of the parts when the lamp is out of action, or when, by accident, the circuit is broken.

As soon, however, as the current passes, the core, B, is sucked into the cylindrical cavity of the bobbin, A, and in being raised also raises the washer by its finger, D, and with it the rod and upper carbon, C, until the voltaic arc is established and the light produced.

A pair of springs is shown, one on either side of the core, B. The action of those spirals of steel is

to support the weight of the core, B, with the aid of the induced magnetic attraction when the current passes. As the carbons are consumed the length of the voltaic arc increases, and with the resistance the current diminishes in strength. This weakens the magnetic pull of the wire coil, and the core, B, with the rod, C, and upper carbon move downwards by the action of gravity, until the consequent shortening of the voltaic arc so diminishes the resistance and increases the strength of the current that this downward movement is stopped by the increasing pull of the magnetic helix, A. After some time, however, the clutch washer, D, will reach its floor or plate, and its downward movement will be stopped, when any downward movement of the core, B, however slight, will at once affect the rod, C, allowing it to slide through the washer until arrested by the upward movement of the core, B, due to an increase of magnetism. The working of this lamp is very steady, and there is very little sluggishness in responding to changes in the strength of the current.

Experiments with this lamp and the machine invented by Mr. Brush have shown the practicability of working as many as 6 to 10 of the lights in one circuit. It is further stated by the inventor that lights of 2,000 candle-power each have been produced in each lamp under the above conditions. The system allows of great electric power being worked upon the circuit, even up to 30,000 standard candlelight.

The Thomson-Houston Lamp.

Professors Thomson and Houston, of the Philadelphia High School, having been engaged in an extended series of experimental researches on dynamo-electric machines and their application to electric lighting, have had their attention directed to the production of a system that will permit the use of a feebler current for producing an electric light than that ordinarily required, or, in other words, the use, when required, of a current of insufficient intensity to produce a continuous arc of the light.

When an electrical current, which flows through a conductor of considerable length, is suddenly broken, a bright flash, called the extra spark, appears at the point of separation. This extra spark will appear although the current is not sufficient to sustain an arc of an appreciable length at the point of separation.

In their system one or both of the electrodes, which may be ordinary carbon rods, are caused to vibrate to and from each other. The electrodes are placed at such a distance apart that in their motion towards each other they touch, and afterwards recede a distance apart which can be regulated. These motions or vibrations are made to follow one another at such a rate that the effect of the light produced is continuous, for, as is well known, when flashes of light follow one another at a rate greater than 25 to 30 per second, the

effect produced is that of a continuous light. The vibrating motions may be communicated to the electrodes by any suitable device, such, for example, as mechanism operated by a coiled spring, a weight, compressed air, &c., but it is evident that the current itself furnishes the most direct method of obtaining such motion.

In a practicable lamp, instead of vibrating both electrodes, it is found necessary to give motion to but one, and since the negative electrode may be made of such size as to waste very slowly, motion is imparted to it in preference to the positive. The carbon electrodes may be replaced by those of various substances of sufficient conducting power. In this system, when desired, an independent current is employed to control the extinction and lighting of each lamp. The following is a description of one of the forms of electric lamp which Messrs. Thomson and Houston have devised to be used in connection with their system of electric illumination.

Fig. 80 exhibits the construction. A flexible bar of metal, *b*, is firmly attached at one of its ends to a pillar, *p*, and bears at its free end an iron armature, *a*, placed over the adjustable pole piece of the electro-magnet, *m*. A metal collar, *c*, supports the negative electrode, the positive electrode being supported by an arm, *j*, attached to the pillar, *p*. The pillar, *p*, is divided by insulation at *i* into two sections, the upper one of which conveys the current from the binding-screw marked + to

the arm j , and the rod R , supporting the positive electrode.

The magnet, m , is placed as shown by the dotted lines, in the circuit which produces the light. The pillar, p , is hollow, and has an insulated conducting

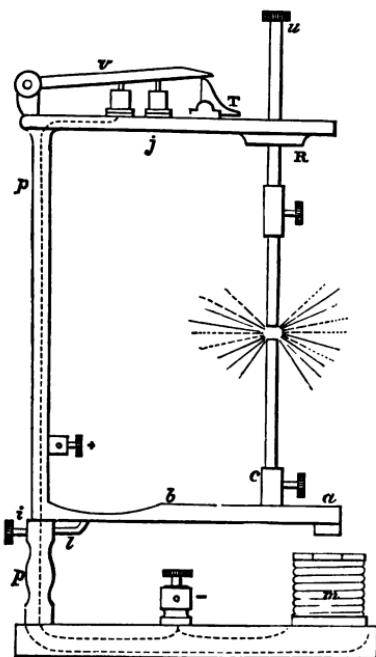


Fig. 80.—Thomson-Houston Lamp.

rod, b , again restores the contact.

During the movement of the negative electrode, since it is caused to occur many times in a second, the positive electrode, though partially free to fall, cannot follow the rapid motions of the negative electrode, and, therefore, does not rest in

permanent contact with it. The slow fall of the positive electrode may be insured either by properly proportioning its weight, or by partly counterpoising it. The positive electrode thus becomes self-feeding. The rapidity of movement of the negative electrode may be controlled by means of the rigid bar, *l*, which acts, practically, to shorten or lengthen the part vibrating. In order to obtain an excellent but free contact of the arm, *j*, with the positive electrode, the rod, *R*, made of iron or other suitable metal, passes through a cavity filled with mercury, placed in electrical contact with the arm, *j*. Since the mercury does not wet the metal rod, *R*, or the sides of the opening through which it passes, free movement of the rod is allowed without any escape of the mercury.

In order to prevent a break from occurring in the circuit when the electrodes are consumed, a button, *u*, is attached to the upper extremity of the rod, *R*, at such a distance that when the carbons are consumed as much as is deemed desirable, it comes into contact with a tripping lever, *T*, which then allows two conducting plugs attached to the bar, *v*, to fall into their respective mercury cups, attached respectively to the positive and negative bind-posts by a direct wire. This action practically cuts the lamp out of circuit.

The Wallace-Farmer Lamp.

Fig. 81 is an illustration of this lamp. Various devices have been resorted to, to cause the carbons

of ordinary shape to automatically approach each other as they are consumed, and the Wallace lamp is not only of an improved description, but its automatic arrangement is of the most perfect kind yet tried.

A A are two *plates* of carefully prepared carbon, and the object of this invention is to so cause the

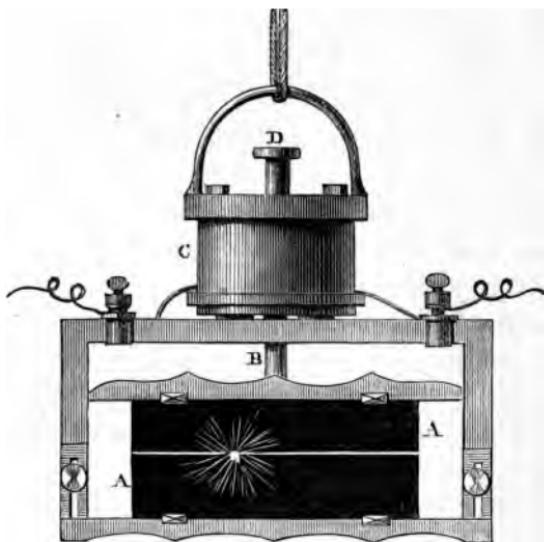


Fig. 81.—The Wallace-Farmer Lamp.

light to burn between them, that the automatic adjustment so often necessary in other lamps is here only necessary about every half-hour. The plates in the latest form of this lamp are about 9 in. long, 5 broad, and the upper is double the thickness of the under—this thickness in turn depending upon the strength of current to be employed. The

lower plate is fixed to the frame, but the upper plate is under the control of an electro-magnet through the rod B. This provides for the contact between or separation of the plates, as the current may require, to produce the maximum amount of light. The electro-magnetic arrangement, C, consists of an ordinary electro-magnet, having its poles downwards, and the rod D B has attached to it a soft-iron armature. When no current passes, the electro-magnet has no effect, and one carbon rests upon another; but when the current is passed, the arc of light forms where there is least resistance, and the electro-magnet at the same instant pulls up the upper carbon and makes the required separation. The distance between the plates may be regulated to a nicety to suit any current.

The light, as has been said, starts at the point of least resistance, and it burns its way horizontally along the carbon edges and back again until the distance is too great, when it is necessary to screw down the rod D a turn or two. In this way the lamp may burn for nearly 100 hours at a time. As many as 10 of these lamps have been maintained in circuit of a Wallace-Farmer machine. It has been well tried in England, and gives every satisfaction. It is, however, unsuited to purposes requiring the light to be kept in one point.

This lamp really supersedes almost every other arrangement for general purposes, and its simplicity is a feature of the greatest importance. The author can speak of its performance as almost

perfect for outside or inside diffused illumination.

Rapieff's Lamp.

The leading peculiarity of M. Rapieff's lamp consists of the duplex carbons used. Most other lamps employ only one solid carbon rod for each burning point; but Rapieff uses two—that is, four altogether. These rods are inclined to each other to form one upright and one inverted V, and at the point of intersection the electric arc is produced as in other lamps. The rods used by this inventor are necessarily of half the sectional area they would have if not double.



Fig. 82.—Rapieff's Lamp.

Fig. 82 will give some definite idea of these arrangements, where the four rods are seen in the interior of a glass globe nearly in contact. The upper pair of rods are always the longer, because they burn away the faster. The duplicate arrangement of the rods has the advantage that one of them may be removed and renewed without extinguishing the light, and this is the chief advantage of the whole arrangement. As soon as the lamp has nearly burnt its carbons, they may be renewed without much disturbing the light. This inventor

also recognises the advantage of making the electrical contact with the rods as near to their points as possible. This has the effect of greatly decreasing the resistance of the lamp.

The upper carbons are free to slide in their holders, and as their points come into actual contact, they are stopped from further motion. As far as this end of the circuit is concerned it is self-feeding, for as fast as the points burn away the length is renewed by their weight pressing them downwards.

When the current is stopped, the two pairs of points come together by movement on the part of the lower pair only. As long as the current does not pass, a light spring supports the lower pair, and gently presses them against the upper pair. Fastened to the free end of both upper carbons is a silk thread, which passes over a pulley and is attached to a sliding-weight in the supporting-pillar of the lamp. As soon as the current passes the lower pair of carbons is caused through its spring to be separated the required distance to produce the voltaic arc. There is communication between the vertical rod actuating the lower carbons and an electro-magnetic arrangement concealed in the base of the lamp.

This consists simply of two electro-magnets, one of which is fixed to the base while the other is pivoted or hinged, and by its approach to the fixed one moves the vertical rod controlling the lower carbons, and these are thus drawn away from the

upper pair. When the current ceases to pass, the spring before spoken of causes the hinged magnet to fall into its normal position, and the lower carbons at the same time touch the upper pair to be in readiness to start the light when the current next passes.

Another good feature of the Rapieff lamp is its arrangement (also concealed in the foot) for throwing a resistance of wire, equivalent to that of the lamp, into circuit when, through any cause, the circuit has been interrupted in the lamp. When the hinged magnet falls back, it instantly closes the circuit of this resistance of wire, and the machine is not affected, nor does it (the supposed accident) affect any other lamps in the same circuit, since the resistance must remain constant, or very nearly so. There is also employed in these lamps a resistance consisting of a pencil of carbon, and through this, the resistance of which is equal to that of the lamp, the current passes when the lamp breaks circuit.

By means of these carefully thought out arrangements, as many as 6 and 8 lamps of this type have been kept alight upon one circuit only, and any accident to one lamp did not affect the others; or any lamp might be extinguished and relighted without any effect being apparent upon the main circuit.

This system has been in practical use in the composing-room of the *Times* newspaper, and gas is thus entirely replaced by electric lights.

Electricians and others are appreciative of the energy with which the proprietors of the *Times* brought M. Rapieff's system into actual use. The construction of the lamp is not so well carried out as the plan, and the parts are unnecessarily delicate, which should not be the case in a practicable lamp for general use. M. Rapieff has also brought into use a lamp in which both pairs of carbons pass up from underneath, forming an inverted V. The arc impinges upon a piece of lime, which increases the light. M. Rapieff has also invented a "candle."

Urquhart's Lamp.

From a somewhat extensive acquaintance with the various systems of electric-lighting, the author has been able to judge of their advantages and demerits, and to come to some positive conclusions on the chief questions. Most of the best electric lamps in use are far too delicate for general handling, and but too apt to get out of order when most wanted to produce a steady light. Even the Serrin, about which so much has been said, is exceedingly delicate, and although it may give little trouble, if at any time it should go wrong in inexperienced hands, the result is an entire stoppage of operations, and another lamp will not in such a case be probably at hand.

As a brief introduction to the author's design, it has been invented to suit his ideas of a lamp suitable to almost any application of electric light. He has

sought to produce a steady lamp, and one that will give little trouble, that will cast no shadows, and a regulator that may be understood and worked or fed at once by any man of ordinary intelligence.

Figs. 83 and 84 are views of the lamp. The same letters refer to the same parts in both figures.

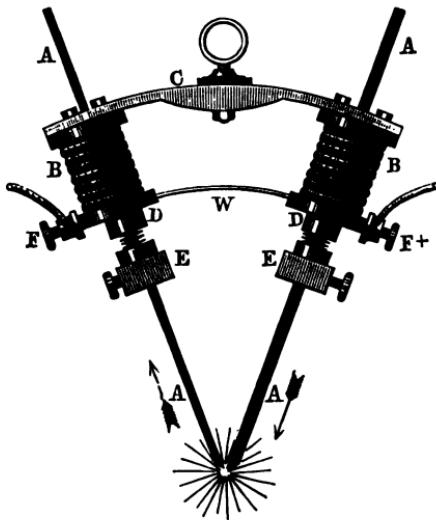


Fig. 83.—Urquhart's Lamp. End.

Fig. 83 is an end view of the lamp, and Fig. 84 a side view.

A A are a pair of carbon plates, carefully made from the best materials used in the composition of rod carbons. These plates are of any suitable length, and 6 inches broad. The length may consequently be 12 inches. These plates are of different thicknesses, the positive one being the thicker because it burns away the faster. They are made

to slide freely through the hollow cores of a pair of flat electro-magnets, B B, which are fastened together by a strong bridge of hard wood, C, provided with a ring for suspending the lamp. The carbon plates pass downwards until they meet at the point where the light is shown, thus forming a V shape. The plates pass also through two hollow armatures, E E, provided with set screws by which

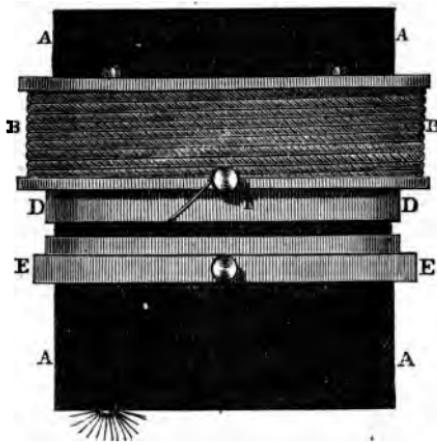


Fig. 84.—Urquhart's Lamp: Side.

the plates and armatures may be made fast together. The armatures are fixed to the magnet cores by a pair of long brass springs, but this might be dispensed with. Fig. 84 will show more clearly how each plate is made to pass through the electro-magnet system. The whole arrangement is exceedingly simple.

When it is required to put carbons in the lamp, plates of suitable size, and about $\frac{1}{4}$ -in. in thickness

for common currents, are selected, passed through the magnets until they touch at their lower edges, and there fastened by the screws, E E. Thus the carbon plates and the armatures are as one, and are free to move up and down to the point where the plates meet. The current enters at F +, passes through the coil of stout wire, B, and is then made to pass to the core of the magnet—including, of course, the armature, which is metallically connected by a spring, and passes down the positive plate, up the negative plate (as shown by the arrows), through the coil of the left-hand magnet, and back to the generator by F.

Suppose that the lamp has been “trimmed;” the plates will be in contact at their lower edges, and the current has a free circuit of little resistance. When it passes, it instantly makes B and B magnetic, which attract the armatures, E E; and, the plates rising with them, the voltaic arc is established, and of such length as may suit the current passing. It is not found necessary to start the arc at one end by inserting a carbon chip.

The arc forms at the point of least resistance between the near edges of the plates, as in the Wallace-Farmer lamp, and from this point it creeps along the edges of the plates to the farthest extremity. The time occupied in doing this will depend upon the strength of current at work, but it may be taken at one hour or so at 2,000 candle-power. When the arc has burned its way from end to end of the plates, the voltaic arc becomes

too long, the current weakens, the magnets release their hold slightly, and the arc is re-established at the length it first had. Thus the action of the lamp is quite motionless for periods of at least half an hour each, and only controls the length of the arc by keeping a constant up-pull upon the plates. It is only about every half-hour that the plates move at all, and when they do move downwards to make up for burnt carbon, the distance for each is very small, or only half that burned off the plate edges.

When the lamp has given light for about 6 hours or more, and it is required to continue for other 6 hours, it is only necessary to slightly lower the plates by the screws in the armatures, E E. In practice this cannot be done just as directed, because the freed armature, having the weight of the plate off it, would be instantly and powerfully attracted, and the current would have to be stopped to free it. The simplest way in which to lower the carbon plates for further consumption is to throw the coil at the required side out of circuit; and to do this it is only necessary to scrape the insulation of a little of the wire leading the current to the binding screw, and to give the bared wire a twist around the pinch screw at E. Thus the magnet will be powerless on that side, and the light will not be extinguished. The screw at E may then be slackened, and the plate tapped downwards a little. It is found that about $\frac{1}{16}$ th of an inch will suffice for 5 hours' work. In

order to obviate the necessity to even thus far disturb the lamp, the pinch screw may be set "easy"—that is, not hard against the plate; and when it is required to lower the latter, a tap or two with any wooden handle will suffice.

This lamp will burn without any attention, and quite steadily, for at the least 6 hours, and often for 12 hours. If it is looked to every 6 hours or thereabouts, and the plates tapped a little downwards, it will burn for periods ranging from 50 to 120 hours with plates of moderate size.

It gives little resistance to the current, as the magnets are coiled with one layer of No. 10 wire only, and the size of the carbon plates permits of a very low resistance in that direction. There is, further, the advantage that the resistance of this lamp is almost constant, and does not vary, like Serrin's regulator, from perhaps 5 ohms to 10 ohms in a few hours. The resistance here is more constant than that obtained in Rapieff's lamp.

There is no fear that the plates may be lowered too far in adding to the length for further work. If the plates are too near to each other, the current will be strengthened, and the magnets will respond by pulling them up to the required length of arc, if the length is not obviously excessive.

w, in the first figure, is a reflecting surface of polished metal or other suitable material; it serves to throw any light diffused upwards in a condensed beam through the carbon separation; and, to insure that no light is lost, this reflected portion

may be thrown downwards quite clear of the arc itself, by making one end of the reflector slightly higher than the other.

The author has found it best in practice, and conducive to steady working, to employ between the pole pieces and the armatures a brass spring, made from a few turns of hard brass wire, as exhibited by the first figure.

The plates slide quite freely through the magnet cores, and would do the same through the armatures if not pinched by the set screws. These magnet cores, being hollow, are best made from pattern in malleable cast iron, and the armatures may also be of this material. The wire is wound upon the core direct, and the flanges shown are cast with the core as one. The aperture provided through the core is $6\frac{1}{2}$ inches long, and $\frac{3}{8}$ in. wide; so that any size of carbon, up to 6 in. wide and nearly $\frac{3}{8}$ in. thick, may be burned.

The wooden bridge is of this material to completely insulate the two sides from each other. It is 7 inches long, and is bolted to the bobbin ends or flanges. The reflector, *w*, must not connect these together metallically, but must have wooden or rubber ends.

Binding screws, *F*, *F+*, are provided as usual. They are insulated from the metallic flange by being screwed into a block of wood or ebonite, set in a dove-tailed aperture cut in it. One end of the coil, *B*, is connected to the screw, and the other to the metal of the magnet itself; to secure which

connection it is only necessary to strip the commencing end, lay it in metallic contact with the magnet, and wind the wire over it, the finishing end being made fast to the screw.

As the carbon plates slide within the cores, and in metallic connection therewith, there is an electrical communication here; but as the armature is apt to hold the thinner plates clear of the magnet altogether, various devices may be adopted to insure a metallic contact with the carbon. It will be found that the spring employed between the armature and magnet will insure this without further trouble.

This spring should, for convenience, be fastened to the magnet core and the armature, and the author finds it most convenient to make a recess in the upper face of the armature to receive the coils of the spring when they are compressed by strong magnetism. The armatures are thus always connected by the springs to the cores, and cannot get lost, while this relationship renders the fitting of new plates very easy. The inexperienced workman has only to push down the plates until their edges meet at the point indicated, or simply until their edges meet, and then to screw up the pinches, E E, when the lamp is ready for work and may be left by itself for hours together.

It will be noted that remarks are made in preceding pages concerning the fact that a horizontal arc does not give so much light as a vertical one. It may be thought that the lamp shown with

this description will give a horizontal light or arc ; but this is not the case, because one carbon is always, from causes affecting the attraction, above the other, and the light takes place in a diagonal line. The lamp will also burn in a horizontal position when required. It is strong, cannot possibly get out of working condition, since there is no mechanism, and otherwise is fitted for general illumination by electricity. It is best hung from some point above the space to be illuminated, and it will be found in this position to cast no shadow whatever downwards or to either side under it. The bridge, C, may be of iron if it is insulated by wood or rubber packing from the metal work at one end only.

In using very light carbons, it may be necessary to weight them a little by slipping a piece of bent sheet lead over the top. This may remain on until the carbon is consumed. It is not necessary to have the upper half of the plate of carbon ; it may be of brass. This will save carbon.

Rotating Disc Lamps.

Many attempts have been made since 1846 to produce a good lamp having rotating discs of carbon instead of the usual rods. Wright was the first to employ this idea, and it has been copied by several others, with modifications and improvements from time to time.

The discs revolve regularly upon two metal axles, put in connection with the poles of the

battery or other generator of electricity, and present successively, by the combined rotation and approximation provided, all the extreme points of their circumferences to the production and emission of the electric light. At each revolution of the discs, they are caused to approach each other by the distance they have burned inwards from the edge, to make the length of the arc constant.

Many different kinds of apparatus may be employed to cause the discs both to regularly rotate, and also at each revolution to approach each other by the exact distance consumed. It has been done by means of clockwork and a spring or weight, and electro-magnetism is, of course, also available for the same purpose. Le Molt, whose lamp was produced and patented in 1849, produced the motion by the first method, and he employed cams upon a large brass disc to make up for the burnt portion of the carbon discs employed. This lamp would burn for over twenty hours at a time.

A great objection to this class of lamps lies in the fact that it is almost impossible to produce discs of sufficient purity to burn equal spaces in equal times, so that a regular motion is in practice of no use. The motion, however it is produced, must be under the direct control of the current itself, so that any augmentation of space burnt over may be compensated for by greater speed in the discs, and a decrease of carbon space burnt by less speed. Arranged vertically, one disc edge

above the other, and thus controlled, there is no reason why this should not make a good continuous lamp.

Lamps in which the Carbons touch.

In the lamps previously mentioned, the carbons are, by clockwork, electro-magnets, or weights kept automatically at a distance apart, so as to form the voltaic arc; in another class of lamps the carbons actually touch, and the light is emitted through the incandescence of the carbon at and near the points of contact, and also by arcs formed between points immediately around the points of contact, the resistance at the point of contact being sufficient to cause a portion of the current to form a belt of heated air forming the arc between the portions of the carbon situated near the point of contact.

Reynier's Lamp.

Reynier's improved lamp works with a rod and a disc of carbon. The rod is placed vertically as usual in other lamps, and fixed to the upper arm. This upper arm of the lamp is movable as in Serrin's lamp, and is also toothed. The support and the carbon rod thus move downwards together.

The racked bar, as it descends by its own weight, carrying its carbon rod, is made to impart motion to a pinion, which in turn rotates, through a larger wheel, the carbon disc employed. Thus the disc rotates in obedience to the descent of the

upper carbon, and it will be evident that the carbon rod also acts as a brake upon the rotating disc to prevent too free a motion.

One peculiarity of the Reynier lamp is its employment of incandescence in the rod used. This carbon pencil is small although long, and the current is not made to traverse the whole of its length. The current is communicated to it a little way above its contact with the revolving carbon disc, and the part of the rod between where the contact is made with the conductor and its end is made white hot, and emits considerable light and heat.

It will be inferred that the unequal burning away of the disc, as it is softer or harder, must cause irregularities in the light, and this is in the foregoing construction really the case.

Some recent improvements made by the inventor, however, make the light almost perfectly steady. The revolution of the turning disc is obtained from the tangential component of the pressure of the carbon pencil on the circumference of the disc. Thus the burning end of the pencil never leaves the moving contact, and it is said that all previous causes of irregularity are thus obviated. There is a brake retarding the progress of the rod, and it is operated thus:—The contact wheel is carried by a lever. The pressure exerted by the carbon on the wheel causes a shoe to press upon the face of a wheel, which is revolved by means of the weight of the holder rod through its rack and pinion. This lamp is suited for the weakest cur-

rents and displays of light, down to the current from 5 Bunsen cells.

Werdermann's Lamp.

The principle embodied in the construction of this lamp is of much value. It is almost a true incandescent lamp, and in this respect may be compared to the Reynier apparatus.

Fig. 85 represents the Werdermann regulator. A is a rounded block of carbon, connected to the negative wire from the machine or battery. B is a rod of carbon, constantly urged upwards against A by a weight, G, acting through a cord over a pulley as shown. It will thus be seen that the lamp is altogether of very simple construction, and has no clockwork or other regulating mechanism.

The inventor states that there is a repulsion between the carbon block and the point sufficient to cause a slight separation, so that the lamp is not simply an incandescent one, but possesses some of the peculiarities and advantages of open circuit lamps. When the current is passed, the carbon rod, at its extreme upper end, becomes white, and glows with a clear, steady light. For this purpose a thin rod is used.

The chief advantage claimed by the inventor lies in the fact that several of these lamps may be placed in one circuit, or, more correctly, in multiple arc connection with the electric source. This connection is made by taking two straight wires from the machine, but not joining their ends, and then

placing the lamps so that they may connect the two wires together through them. The current is thus divided between the lamps, and the result is, or should be, an almost perfect subdivision of the currents. The number placed in one circuit is

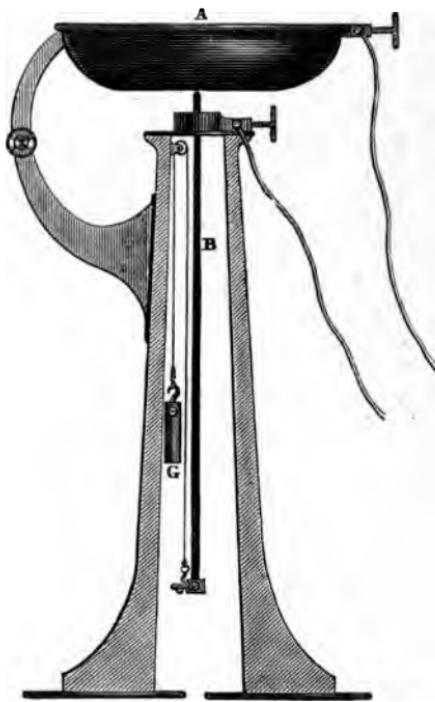


Fig. 85.—Werdermann's Lamp.

limited, however, for when too many are in, the subdivision does not hold good unless the main conductors increase in size with the number.

As many as from 9 to 12 lights of 50-candle power have been maintained with so small a cur-

rent as that from a Gramme plating-machine. When only 2 lamps were upon the circuit they gave, each, a light equal to 320 standard candles. This lamp is decidedly a considerable advance in electric light production. It has been repeatedly exhibited in London.

Crompton's Lamp.

In this lamp the inventor has aimed at reducing the weight of those parts that require movement for the more delicate and final adjustment of the distance between the carbons. In its latest form the mechanism is above the light. The negative carbon is below the positive, and attached by an arm to a rod fast to the armature of the magnet. A spring keeps the armature and rod up, when the magnet is not acting. The positive carbon is fast to a rod which by its weight constantly tends to descend towards the negative carbon, and in doing so by means of a rack causes a train of wheels to work.

On the top of the armature of the magnet is hinged a smaller piece of iron or jockey armature carrying a brake which can act on the train of wheels. A small light spring keeps the brake from touching the wheels until a current sufficiently strong causes, not only the armature to be drawn down and come in contact with the magnet, but also causes the smaller jockey piece on the top of it to be drawn down and apply the brake. The action is as follows: 1. When no current is circu-

lating, the positive descends and touches the negative. 2. On a current being established the electro-magnet draws down the armature, thus lowering the negative away from the positive and establishing the arc. 3. The positive then begins to fall until the current becomes sufficiently strong to attract the small jockey armature, causing the brake to be applied and stopping the descent of the positive. The lamp is very sensitive, as, instead of having several pounds to be thrown in and out of motion for each adjustment, the portion to be moved by the change of current is only a few grains. The adjustment consequently takes place every few seconds. The price of this lamp is £12 10s.

The Brougham-André Lamp.

In this lamp a carbon rod, weighted, falls on to a cone of copper, the carbon being the positive electrode and the copper the negative. The carbon rod is inside a brass tube, and the copper cone is fast to an arm connected by a rod to another tube outside the one containing the carbon rod, and insulated from it. The outer brass tube is joined to a brass disc, to which is fastened the glass case enveloping the light, and this is kept air-tight by being immersed in a second glass case filled with water. Thus an air-tight joint is obtained and the light soon exhausts the oxygen, leaving gases which do not combine with carbon.

While the carbon burns away at the rate of six

inches per hour in the open air, it burns only one-eighth of an inch per hour when in the water-covered globe.

Lugo's Carbons.

This patented arrangement of carbons is the invention of Orazio Lugo, of Flushing, N.Y. It consists chiefly in making the carbon rods hollow, so that air may pass through them to keep down the temperature. The inventor also mentions the possibility of increasing or modifying the intensity of the light by the introduction of various fluids or substances through such apertures. It is not, however, very clear as to what these fluids are to consist of. The air may also be forced.

Electric Candles.

In all the arrangements previously described some means of moving the carbons, either by springs or gravity, is employed, but if two rods of carbon are placed parallel, the arc, it is found, can be maintained between them, if the currents are used alternately in different directions so as to consume the carbons equally. This idea first occurred to M. Jablochhoff, and is called an electric candle, as the carbons consume away from one end in the same way as the wick and wax of a candle. It was first thought necessary to have an insulating material between the rods, but this has been found unnecessary.

M. JablochkoFF's Candle.

In March, 1876, this "candle" was patented and introduced, and a remarkable movement towards the application of electric lights to public purposes was in consequence instituted. In Paris it took the form of lighting the Avenue de l'Opéra, the Place de l'Opéra, the Place du Théâtre Français, and numerous public buildings; and in consequence of the success attending these applications of the new light, it was tried successfully in workshops, railway depôts, and other places on the Continent and in America, while the same impetus carried the electric light to the Thames Embankment and other public places in London and the provinces.

The "candle" just mentioned consists of two rods of manufactured carbon, placed side by side, and insulated from each other by a strip of plaster of Paris, or kaolin, which was at first used for the purpose. Figs. 86 and 87 show the rods and the complete candle. The rods used are about $\frac{3}{16}$ ths of an inch in diameter, and from 5 to 15 inches in length. They are stuck in a pair of brass tubes, which are held together by a cement of earthy matter, B. Across the top is a chip of carbon fastened in place by carbon powder and gum, and when the alternating currents pass this is fused and the true electric arc instituted.

Fig. 88 shows a burning candle, and Fig. 89 is from a photograph of a candle partly burnt on the

Thames Embankment. Both rods burn equally, on account of the alternating currents, which must always be employed with the candle with this very object, and the plaster of Paris is fused as the candle burns down.

The candles most in use are ten inches long, and burn for about $1\frac{1}{2}$ hours; and if a candle goes out it cannot again be conveniently relighted—that is, it will not relight itself, as a good lamp or some other candles will. Four candles are placed in one lamp, which has usually a cover of opalescent glass to tone down the intense glare. When one candle goes out, or before it goes out, another is switched into the circuit, either by hand or by an automatic arrangement—which, however, does not appear to have had extensive application. Twenty of the lamps on the Thames Embankment are self-light-

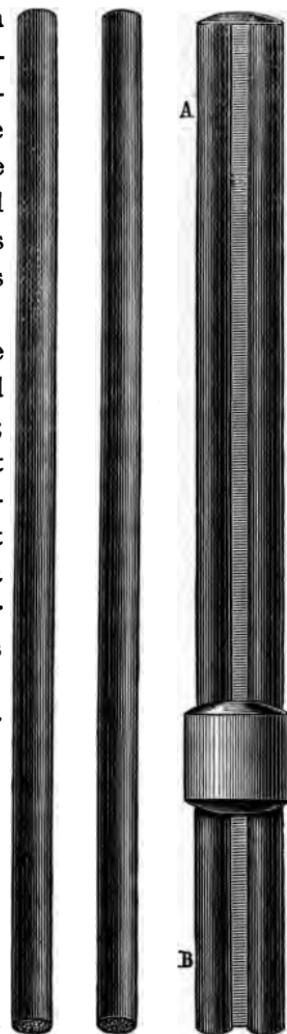


Fig. 86.—Carbon Rods.

Fig. 87.—Complete Candlc.

ing as the candles burn down, and twenty are switched by hand.

Figs. 90 and 91 represent holders for the candles.

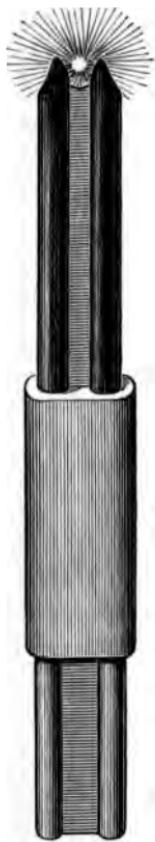


Fig. 88.—Jablochkoff Candle.



Fig. 89.—From Photo of half-burnt Candle.

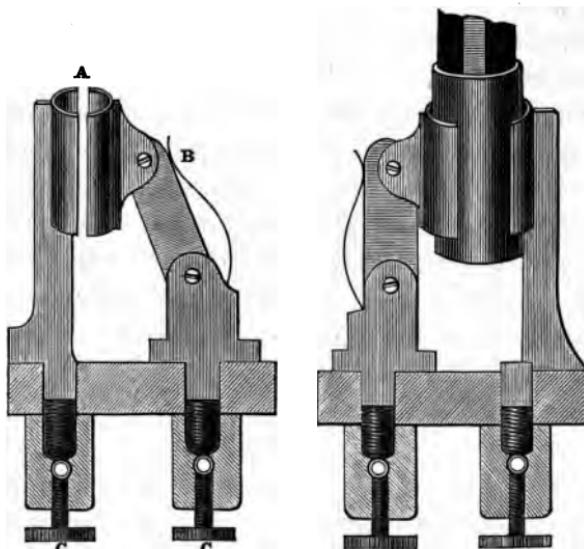
They consist simply of two cheeks insulated from each other, one fixed, A, and the other on a joint with a holding spring, B. The binding-screws, C C, carry the current to the holder.

The automatic switch consists of a metallic finger, which is pressed against the candle by a spring, so that when the candle is consumed down to this point the finger will fall through it, and by its holder underneath switch another candle into circuit. Other more or less complicated arrangements are in use, but they do not carry the same evidences of mature thought as the candle itself would appear to have

induced. Jablochkoff's candle must inevitably give place to other and better devices lately introduced.

Wilde's Candle.

The maker and inventor of the well-known dynamo-electric machine (Mr. Henry Wilde, of Manchester) has also invented a candle and holder superior in many respects to that of M. Jablochkoff. From his experiments in connection with the Jab-



Figs. 90 and 91.—Jablochkoff's Candle-holders.

lochkoff system he deduces several very important conclusions, bearing practically upon the question of electric burners of this type. One of the conditions necessary for producing a constant light from the candle, in its most recent form, was that the strength of the alternating current should be such that the carbons consume at

a rate of from 4 to 5 inches per hour. If the electric current is too powerful, the carbons become unduly heated, and present additional resistance to the passage of the current. The points at the same time lose their regular conical form. If, on the other hand, the current be too weak, the electric arc plays about the points of the carbons in an irregular manner, and the light is easily extinguished by currents of air.

In the course of his experiments, Mr. Wilde was struck by the apparently insignificant part which the insulating material plays in the maintenance of the light between the carbon points; and it occurred to him to try the effect of covering each of the carbons with a thin coating of hydrate of lime, and mounting them parallel to each other in separate holders, without any insulating material between them. The use of the lime covering was intended to prevent the light from travelling down the contiguous sides of the carbons. On completing the electric circuit the light was maintained between the two points, and the carbons were consumed in the same regular manner as when the separation was by means of plaster of Paris.

Two plain cylindrical rods of carbon, $\frac{3}{16}$ ths of an inch in diameter and 8 inches long, were now fixed on the holders, parallel to each other as before, and $\frac{1}{8}$ th of an inch apart. The strength of the alternating current was such that it would fuse an iron wire 0.025 in. in diameter and 8 feet in length. On establishing the electric current through

the points of the carbons, by means of a conducting paste composed of carbon and gum, the light was produced, and the carbons burnt steadily downwards as in the first trials.

Four pairs of naked carbons mounted in this manner were next placed in series on the circuit of a four-light machine, and the light was produced from these carbons simultaneously, as when the insulating material was used between them. The light from the naked carbons was also more regular than that from the insulated ones, as the plaster of Paris insulation did not always consume at the same rate as the carbons, and thereby obstructed the passage of the current. This was evident from the rosy tinge of the light produced by the volatilisation of the calcium simultaneously with the diminution of the brilliancy of the light from the carbons. The only function, therefore, which the insulating material performs in the electric candle, as shown by these experiments, is that it conceals the singular and beautiful property of the alternating current to which attention has been directed.

This simple method of burning the carbons will greatly further the development of the electric light, as carbons can be used of much smaller diameter than has hitherto been possible. They may also be of any desired length, for as they are consumed they may be pushed up through the holders without interrupting the light. One of these developments will be a better method of

lighting coal and other mines. In this application the alternating currents or waves from a powerful electro-magnet induction machine may be used for generating, simultaneously, alternating secondary currents or waves in a number of small induction coils, placed in various parts of the mine. The light may be produced in the secondary circuits from pairs of small carbons enclosed in a glass vessel, having a small aperture to permit the expansion of the heated air within. Diaphragms of wire gauze may be placed over the aperture to prevent the access of explosive gas. By generating secondary currents or waves, without interrupting the continuity of the primary circuit, the contact breaker is dispensed with, and the subdivisions of the light may be carried to a very great extent.

In the course of his experiments, it was observed by Mr. Wilde that when the electric circuit was completed at the bottom of a pair of carbons close to the holders, the arc immediately ascended to the points, where it remained so long as the current was transmitted. His first impression of this peculiar action of the arc was, that it was due to the ascending current of hot air by which it was surrounded. This, however, was found not to be the cause, as the arc travelled towards the points in whatever position the carbons were placed, whether horizontally or vertically in an inverted position. Moreover, when a pair of carbons was held in the middle by the holders, the arc travelled

upwards or downwards to the points, according as the circuit was established above or below the holders. The action was in fact recognised to be the same as that which determines the propagation of an electric current through two rectilinear and parallel conductors submerged in contact with the terrestrial bed, which was described by the same experimenter in the scientific papers of August, 1868.

In all the arrangements in general use for regulating the electric light, when the light is required the ends of the carbon pencils are brought into momentary contact, and are then separated a short distance to enable the light to form between them. The peculiar behaviour of the electric arc when the carbons are placed parallel to each other suggested to Mr. Wilde the means of lighting the carbons automatically, notwithstanding the fact that they could only be made to approach each other by a motion laterally, and to come into contact at their adjacent sides. To accomplish this object, one of the carbon holders is articulated (jointed) or hinged to a small base plate of cast iron, Fig. 92, C, which is so constructed as to become an electro-magnet when coiled with a few turns of insulated wire, E. The carbon holder, B B, is made in the form of a right-angled lever, to the short horizontal limb of which is fixed an armature, D, placed over the poles of the electro-magnet, E. When the movable and fixed carbon holders are brought into juxtaposition, and the carbons inserted in them, the upper parts

of the two carbons are always in contact when no current is transmitted through them, as shown by the dotted lines in the engraving.

The contact between the carbons is maintained by means of an antagonistic spring, inserted in a recess in one of the poles of the electro-magnet,

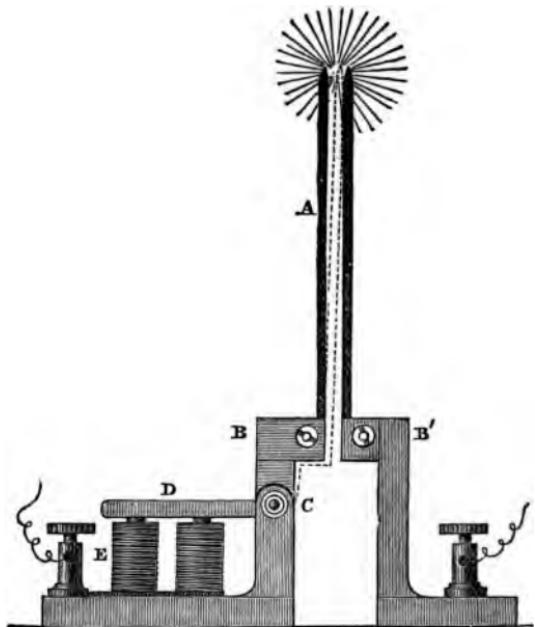


Fig. 92.—Wilde's Candle.

and reacting on the under side of the armature. One extremity of the coil of the electro-magnet is in metallic connection with the base of the carbon holder, while the other extremity of the coil is in connection with the terminal screw at the base of the instrument, from which it is, of course, insulated.

The coils of the electro-magnet are thus placed in the same circuit as the carbon pencils.

When the alternating current from a dynamo-electric machine is transmitted to the carbons, the electro-magnet attracts the armature and separates the upper ends of the carbons, which bring them into this normal position, and the light is immediately produced. When the circuit is interrupted the armature is released, the upper ends of the carbons come into contact, and the light is produced as before. When several pairs of carbons are placed in the same circuit, they are by these arrangements lighted simultaneously.

Jamain's Blowpipe Lamp.

A curious application of Mr. Wilde's electric candle has been devised by M. Jamain, who, in a communication to the French Academy of Sciences, gives details from which the following description has been deduced:—Wilde's candle, as is well known, consists of a pair of thin carbon rods separated from each other, the arc forming between them as mentioned in the description given in this work. M. Jamain takes the negative electrode leading from the electrical generator, and, instead of fastening it in the binding-screw at once, makes it describe one or two turns around the candle, from top to bottom, as in Fig. 93, where A is the candle, and the negative electrode is wound one turn round the candle longitudinally,

as indicated by the arrows. It will be seen that the direction of the electric arc coincides with that of the outside current. The result of thus arranging the parts is that when the arc is formed it flares up like a gas flame, being attracted by the passing current. M. Jamain then causes it to impinge upon a cylinder of chalk or lime, as in the

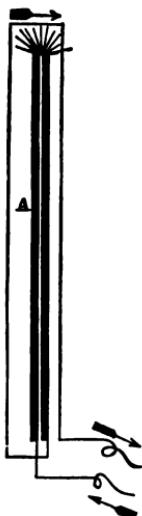


Fig. 93.—Jamain's
Blowpipe Candle.

lime or Drummond light. He also employs magnesia. It has the effect of very greatly augmenting the amount of light, and of toning its quality from violet to yellowish green or white by the action of the lime. The heat is so intense as even to fuse the chalk, so that the inventor recommends its use to chemists and others as probably the most powerful flame known. It is, as yet, however, too expensive except upon a small scale. It would appear to be necessary in practice to provide some arrangement to move the lime body downwards to coincide with the receding carbon points.

De Meritens' Candle.

A device by De Meritens would appear to extend the candle idea in another direction. This inventor employs a third rod of carbon between the other two, but not in contact with them. It is preferred to have it of half the diameter of the outside rods,

and it occupies the place, and partly fulfils the function, of the insulating plaster of Paris or air.

The arc, once produced by any convenient means, plays between the outer rods and the central one, which it consumes. When the arc is thus divided between three rods it has less chance to be extinguished than in Jablochhoff's original candle. And the inventor considers that less power will in this case be necessary to produce an electric light of given power.

Rapieff and Siemens' Candles.

M. Rapieff and Dr. Siemens have produced candle lamps. Their construction is different from that of Wilde, but the principle and the results are so exactly similar in both cases to that of Wilde that it will be unnecessary to go into details. Wilde's holder, on account of its beautiful simplicity, will probably be found the best in use.

Incandescence in Vacuo and Gas.

Graphite, generally known as gas carbon, is really the only material which has as yet been found of service in the production of electric light. Refractory metals have been tried, but they all burn too quickly, or emit a very unsuitable light.

Carbon, in the form of graphite, is almost universally used. When carbon is burnt by electricity in air, the consumption is considerable, and it is reduced very materially when the carbons are burnt

in a vacuum. It will be understood from this that the production of electric light needs no aid from the oxygen of the air, as do almost every other kind of light. It is as easily produced in a vacuum as in free air.

Owing to the fact that a saving is effected when the light is produced in *vacuo*, many inventors have turned their attention to this section of the subject, which when first suggested promised much, but the attendant complications gradually overcame the advantages, and the methods were failures.

It was then thought that carbon in the form of thin pencils, enclosed in a glass globe exhausted of air, might, by being rendered highly incandescent by passage of the electric current, afford a permanent source of light, since it was believed that carbon would not burn and waste in *vacuo*. These attempts, although not few in number or undertaken by unskilled hands, have as yet failed, because the carbons always *do* burn and perish. So long ago as 1845 an American inventor, Mr. King, patented there and in England a lamp involving this principle. His light was produced in a vacuum, to prevent the oxidation of the incandescent carbon or metal, and was extremely promising for its beauty, brilliancy, and steadiness. But it failed to be permanent and economical from various defects and deficiencies, some of which have, of course, been removed by the increased power and economy of modern dynamo-electric machines, and

by recent advances in the art of subdividing the electric current.

Messrs. Sawyer and Mann, of New York, have secured patents for a lamp based upon the exhaustion of a glass globe of air, and filling it with pure nitrogen gas, in which the material is to glow permanently. The light is produced by the incandescence of a slender pencil of carbon. The light-giving apparatus is separated from the lower part of the lamp by three diaphragms to shut off downward heat radiation. The copper standards of the lamp are so shaped as to give great radiating surface, so that the conduction of heat downwards to the mechanism of the base is wholly prevented. No detailed description of this lamp will be necessary, further than to say that the electric current enters from below, follows the line of metallic conductors to the burner, thence downwards on the other side to the return circuit. The light-producing portion is, of course, completely insulated, and also sealed at the base gas-tight.

A fatal defect in all previous lamps depending on incandescent carbon has arisen from what has been called the "vaporising" of the carbon. This Mr. Sawyer holds to be an absurdity, since the carbon is not even fused. The wastage of the carbon in mercurial vacuo and in atmospheres of compound gas is due, he holds, to chemical decomposition. Many gases, indifferent to carbon at ordinary temperatures, attack it destructively at temperatures obtained in the electric lamp;

and the process is continuous, the carbon taken from the burner being redeposited on the glass case, and the gas left free to continue its depreciation.

Mr. Sawyer claims to have overcome this difficulty by his method of charging the lamps with pure nitrogen gas only, and by providing for fixing of any residual oxygen left in the lamp. In this way it is claimed that an unwasting carbon is secured. Another stumbling-block, upon which many inventors have come to a standstill, has been the crumbling or disintegration of the carbon burner. This is usually caused by sudden heating when the lamp is first lighted. This is avoided in the Sawyer-Mann lamp by a kind of switch, with the use of which it is impossible to turn all the current on at once, or otherwise than gradually. This, however, the inventor holds, is not the only nor the chief advantage of the switch. It is claimed to be the key to the entire problem, Mr. Sawyer holds, of practicable electric distribution.

A dynamo-electric light company has been formed in America to supply lights upon the Sawyer-Mann system, and they claim for it the following advantages:—It is well known that an electric current will exactly and readily divide among circuits of equal resistance; accordingly, if the resistance of a sub-circuit be maintained constant, no matter what may be going on in it, whether a lamp is not lighted at all or lighted to a mere taper, or to any intermediary stage up to

full brilliancy, it is obvious that no other lamps in circuit will be affected.

The greater part of the illumination produced on this system is the product of a small part of the current. When the light is well on, a very slight increase in the current increases the light enormously. It is here that the great loss occasioned by dividing a fixed current among several lamps finds its explanation.

A current that suffices in one lamp to produce a light, say, of 100 candles, will, if divided between 2 lamps, give in each, perhaps, no more than 20 candles, or even 10, making a loss of 80 candles in the sum total. But if the current be doubled, each lamp will give a light of 100 candles, and the sum total will be 200 candles instead of 20. Having brought a candle or a system of candles up to the point of feeble incandescence, a (proportionally) small addition to the current will make them all brilliant. If at $6,000^{\circ}$ Fahr. a given carbon will produce a light of 3 candles, at $12,000^{\circ}$ Fahr. it will give 9 candles, and at $24,000^{\circ}$ Fahr. it will give 81 candles; the illuminating power increasing with vastly greater rapidity than the temperature. The wires supplying the current may be run through existing gas pipes, each lamp being provided with a switch placed conveniently in the wall: and by simply turning a key the light is turned up and down, off or on. So long as the house is connected with the main, it makes no difference to the producer whether all the lights

are on or off, since the existence of the entire house resistance remains the same; though a difference will be caused to the consumer, since a meter records the time that each lamp is on, and the charge is rated accordingly.

When the main is tapped for a sub-circuit, a shunt is introduced so as to throw so much of the current as may be needed into the derived circuit. The resistance of, say, 100 added lamps will be about 1,000 ohms. By giving to the shunt a resistance of 10 ohms, 100th of the current will be diverted, and the lamps supplied. Where a large number of lamps are required in a circuit, a combination of two plans indicated is employed. The diversion of any portion of the electric supply into an added circuit, whether one house or a group of houses, necessarily increases the aggregate resistance of the electric district, and calls for more work from the generator. To meet such contingencies automatically, Messrs. Sawyer and Mann have invented and patented a regulator, which responds instantly to any increase or diminution in the demand, thereby securing an absolutely uniform volume of current.

This regulator so controls the steam or other power actuating the generator of electricity, that the amount of power supplied is increased or diminished in exact proportion to the demand, either by changing the volume of steam produced, or by coupling on or detaching different generators, or parts of a simple generator in circuit.

This system does not appear to have had an extended trial, and it is very doubtful whether the carbon pencils will, in "pure nitrogen," be perfectly permanent. The light obtained by incandescent pencils is much less than that from the open arc with the same current, and the incandescent lamp is in this respect costly, even although a perfectly permanent pencil could be arranged. There is an obvious defect, too, in the Sawyer-Mann system when the resistance of the circuit, and consequently the expenditure, is always the same, whether the lamps are burning or not. This could, no doubt, be obviated.

Such is the best incandescent lamp of this kind that has been invented. M. Fontaine has likewise made many experiments with carbon pencils, but the best of them were consumed as usual in air in 15 minutes. Konn has also invented an incandescent lamp, in which a vacuum is maintained. Other inventors have also produced lamps of little use in practice.

Edison's Lamps.

Much interest has been taken in the sensational and often absurd announcements concerning the apparatus in course of perfection by Mr. T. A. Edison, of Menlo Park, New York. This inventor is well known by his talking phonograph and telephones, and it was in some quarters thought that when he had set himself to the task of inventing an efficient subdivision of the electric light circuit,

something would in all probability be done. Unfortunately, however, as far as can be learned up to this date (July, 1879), the attempts have proved almost complete failures; but it is to be hoped that if Mr. Edison continues his investigations the ultimate outcome may be of much value.

Edison's lamp, Fig. 94 (for only one is deserving of notice), is based upon a very old idea—the incandescence of platinum, which was employed by

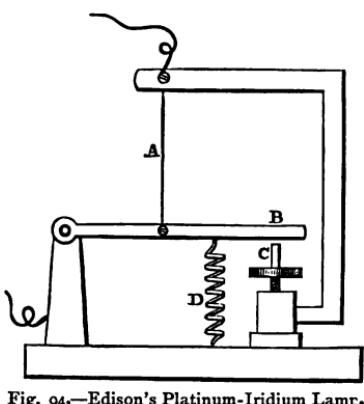


Fig. 94.—Edison's Platinum-Iridium Lamp.

various inventors, and by King, as early as 1845. All such lamps have so far been failures, and have proved wasteful of current, inasmuch as the true arc gives much more light for the same expenditure of power in the circuit. Edison's

device, however, would appear to depend almost altogether for its usefulness upon an automatic regulator attached to it, and it has proved that automatic apparatus of this class work very indifferently. He employs, first, a strip of an alloy of platinum and iridium, A. This is fastened between two holders, the lower one of which is a lever, B, jointed at one end. This lever is provided with a spiral spring, D, constantly stretching the platinum-iridium strip, and under its end is a contact point, C. When

the current passes the strip is made white hot, and gives out considerable light before it fuses. The expansion consequent upon this allows the antagonistic spring to put the strip out of circuit for an instant when it is in danger of being fused by the strength of current. Unfortunately, however, the expansibility of platinum is extremely small, and although the lever provided multiplies the expansion into a considerable movement, the platinum-iridium strip is very often fused before it can act. It is, in fact, extremely doubtful whether any regulator of current upon this principle will ever be devised.

It must not be forgotten, also, that any contact points in the circuit of a dynamo-electric machine will never work well. There is a powerful discharge of stored-up electric energy as soon as the circuit is broken, and what contact points will withstand such sparks? If there is to be regulation of circuit at all, it must be by means of some substance upon which pressure acts to increase or decrease the resistance, and not by open contact. It is, in short, not difficult to see that the obstacles which stand in the way of inventing a useful lamp on this system are of a kind difficult of removal. The expansion of this lamp itself when it becomes heated would suffice to render useless any contacts or adjustments previously made. The apparatus is too delicate, and may be said to be useless in any but skilled hands. The idea of regulating the current has been tried in various pieces of appa-

ratus intended to automatically govern the circuit of a dynamo-electric machine, and which are here spoken of under "Regulators of Current," p. 160.

Edison's lamp has been tried in England, but the results were anything but satisfactory, considering that it was originally intended to be applicable to general household purposes.

The *Times* of March 22nd, 1879, went so far as to say that Mr. Edison never did accomplish more than to maintain 400 coiled iron wires in a state of partial incandescence with current derived from the power of a 16 horse-power engine. This is wrong. Mr. Edison has produced several lamps of the platinum description, and with them some real subdivision has been effected, and it is very improbable indeed that iron wire would be chosen by him from which to obtain light by incandescence.

From private experiments made with Edison's apparatus, and modifications of it, the greatest care was found to be necessary to prevent the instant melting of the incandescent strip, and if the regulator is not adjusted with the greatest accuracy, the strip disappears under the energy in a twinkling.

Mr. Edison has also employed lamps made with platinum wire spirals, regulated again by expansion, and a break in the circuit. He also proposes the use of secondary currents and induction coils, and also secondary batteries in circuit.

With regard to the platinum-iridium spirals for use in Mr. Edison's lamps, a communication by the inventor himself, read before the American Asso-

ciation for the Advancement of Science, contains some interesting particulars of a new method by which they may be prepared for use in electric illumination.

In the course of his experiments on electric lighting he has developed some striking phenomena arising from the heating of metals by flames and by the electric current, especially wires of platinum, and platinum alloyed with iridium. These experiments are still in progress. The first fact observed was that platinum lost weight when treated in a flame of hydrogen, that the metal coloured the flame green, and that these two results combined until the whole of the platinum in contact with the flame had disappeared. A platinum wire, 20,000th of an inch in diameter, was wound in the form of a spiral one-eighth of an inch in diameter and half an inch in length. The two ends of the spiral were secured to clamping posts, and the whole apparatus was covered with a glass shade. Upon bringing the spiral to incandescence for 20 minutes, that part of the globe in line with the sides of the spiral became slightly darkened; in five hours the deposit became so thick that the incandescent spiral could not be seen through the deposit.

This film, which was most perfect, consists of platinum, and Mr. Edison has no doubt but large plates of glass might be coated economically by placing them on each side of a large sheet of platinum, kept incandescent by the electric current.

This loss in weight, together with the deposit

upon the glass, presented a very serious obstacle to the use of metallic wires for giving light by incandescence ; but this was easily surmounted after the cause was ascertained. He coated the wire forming the spiral with the oxide of magnesium by dusting upon it finely powdered acetate of magnesium. While incandescent the salt was decomposed by the heat, and there remained a strongly adherent coating of the oxide. This spiral so coated was covered with a glass shade and brought to incandescence for several minutes ; but instead of a deposit of platinum upon the glass, there was a deposit of the oxide of magnesia. From this and other experiments Mr. Edison became convinced that this effect was due to the washing action of the air upon the spiral ; that the loss of weight in and the colouration of the hydrogen flame was also due to the wearing away of the surface of the platina, by the attrition produced by the impact of the stream of gases upon the highly incandescent surface, and not to volatilisation, as commonly supposed.

He further describes other and far more important phenomena observed in his experiments. If a short length of platinum wire, 1,000th of an inch in diameter, be held in the flame of a Bunsen burner, at some part it will fuse and a piece of the wire will be bent at an angle by the action of the globule of melted platinum ; in some cases there are several globules formed simultaneously, and the wire assumes a zig-zag shape. With a wire

4,000th of an inch in diameter this effect does not take place, as the temperature cannot be raised to equal that of the small wire, owing to the increased radiating surface and mass. After heating, if the wire be examined under a microscope, that part of the surface which has been incandescent will be found covered with innumerable cracks. If the wire be placed between clamping posts, and heated to incandescence for 20 minutes by the passage of an electric current, the cracks will be so enlarged as to be seen with the naked eye; the wire under the microscope presents a shrunken appearance, and is full of deep cracks.

If the current is continued for several hours, these effects will so increase that the wire will fall to pieces. This disintegration has been noticed in platinum long subject to the action of a flame, by Professor Draper. The failure of the process of lighting invented by the French chemist, Tessié-du-Motay, who raised sheets of platinum to incandescence by introducing them into a hydrogen flame, was due to the rapid disintegration of the metal. Mr. Edison has ascertained the cause of this phenomenon, and has, he says, succeeded in eliminating that which produces it, and in doing so has produced a metal in a state hitherto unknown, and which is absolutely stable at a temperature when nearly all substances melt or are consumed; a metal which, although originally soft and pliable, becomes as homogeneous as glass and as rigid as steel. When wound in the form of a spiral, it is as springy and

elastic when at the most dazzling incandescence as when cold, and cannot be annealed by any process now commonly known. For the cause of this shrinking and cracking of the wire is due entirely to the expansion of the air in the mechanical and physical pores of the platinum, and the contraction upon the escape of the air. Platinum as sold in commerce may be compared to sandstone, in which the whole is made of a great number of particles with many air spaces. The sandstone upon melting becomes homogeneous, and no air spaces exist. With platinum or any metal the air spaces may be eliminated and the metal made homogeneous by a very simple process.

This process is then described by Mr. Edison. He made a large number of platinum spirals, all of the same size and form and the same quality of wire ; each spiral presented to the air a radiating surface of $3\frac{1}{6}$ of an inch ; 5 of these were brought by the electric current up to the melting-point, the light was measured by a photometer, and the average light was equal to 4 standard candles for each spiral just at the melting-point. One of the same kind of spirals was placed in the receiver of an air-pump, and the air exhausted to 2 millimètres ; a weak current was then passed through the wire to warm it slightly, for the purpose of assisting slightly the passage of the air from the pores of the metal into the vacuum. The temperature of the wire was gradually augmented at intervals of ten minutes until it became red. The

object of slowly increasing the temperature was to allow the air to pass out gradually and not explosively. After which the current was increased at intervals of fifteen minutes. Before each increase in the current the wire was allowed to cool, and the contraction and expansion at these high temperatures caused the wire to weld together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of 25 standard candles, whereas it would undoubtedly have melted before it gave a light of 5 candles had it not been put through the above process. Several more spirals were afterwards tried, with the same result. One spiral which had been brought to these high temperatures more slowly gave a light equal to 30 standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature. Upon examination of those spirals which had passed through the vacuum process, by the aid of a microscope no cracks were visible: the wire had become as white as silver, and had a polish which could not be given it by any other means. The wire had a smaller diameter than before treatment, and it was exceedingly difficult to melt in the oxy-hydrogen flame as compared with the untreated platinum; it was found that it was as hard as the steel wire used in pianos, and that it could not be annealed at any temperature. His experiments with many

metals treated by this process have proved to his satisfaction, and he has no hesitation in stating that which is known as annealing of metals to make them soft and pliable is nothing more than the cracking of the metal. In every case where a hard-drawn wire had been annealed, a powerful microscope revealed myriads of cracks in the metal. Since the experiment just mentioned was made, further investigations, with the aid of Sprengel mercury pumps, produced higher exhaustions, and by consuming five hours in excluding the air from the wire and intermitting the current a great number of times, the result is stated to be the light of 8 standard candles from a spiral of wire with a total radiating surface of $\frac{1}{16}$ th of an inch, or a surface about equal to a grain of buckwheat. With spirals of this small size which have not passed through the process the average amount of light given out before melting is less than one standard candle. Thus Mr. Edison has been enabled, by the increased capacity of platinum to withstand high temperatures, to employ small radiating surfaces, and thus reduce the energy required for electric light.

He now claims to have obtained 8 separate jets, each giving out an absolutely steady light, and each equal to 16 standard candles or a total of 128 candles, by the expenditure of 30,000 foot-lbs. of energy, or less than one horse-power. As a matter of curiosity he made spirals of other metals, and excluded the air from them in the manner stated.

Common iron wire may be made to give a light greater than platinum not treated.

The latest outcome of Mr. Edison's praiseworthy labours to obtain a constant burner by electric agency, is a small lamp in the form of a glass globe, exhausted of air, and containing in the electric circuit a horseshoe-shaped strip of carbonised cardboard.

This horse-shoe is stamped from "Bristol board," and is then placed in a wrought-iron mould and raised to such a temperature that the volatile constituents of the paper are driven off, the result being a miniature horse-shoe (2 in. long) composed of charred paper. Through this, when the containing globe has been exhausted by the air-pump, the current is passed from pole to pole by connections of platinum wire. It is claimed that this substance, which becomes highly incandescent and yields a brilliant light, is unchangeable by heat in *vacuo*, and that a lamp may be produced at an outlay of 25 cents.

A number of these lamps were seen burning in the inventor's laboratory by correspondents of the press, English and American, during the month of December, 1879. The result is stated to be so satisfactory that Mr. Edison intends to illuminate, on a practical scale, the village of Menlo Park, and then to extend the system to New York.

There is little probability, however, that this lamp will prove constant. Burnt paper in various forms has been repeatedly tried before, and it is

assuredly not constant in the best possible vacuum obtainable. Moreover, the resistance of such a substance is very much greater than that of pure carbon in the graphite form. Carbon obtained from paper is obviously very impure, and cannot, therefore, prove constant while incandescent under the electric current, while a strong discharge of electricity throughout the circuit would in all probability split every horseshoe therein. Some time has elapsed since Mr. Edison announced his intention to light Menlo Park, and no further progress can be reported. We may, indeed, rest assured that, upon further reflection, Mr. Edison will abandon this imperfect burner.

Up to the time of going to press (April, 1880) it is reported that Mr. Edison continues his experiments with the carbon loops, and that he is building and fitting a model electric light station, capable of maintaining 500 lights, to demonstrate the practicability of his scheme.

CHAPTER IX.

MEASUREMENT OF ELECTRIC LIGHT.

PHOTOMETRIC measurements, as applied to the light produced by electricity between two carbon points, are not so easily obtained accurately as may be supposed. The value is usually given in terms of comparison with the standard sperm candle, burning, as nearly as possible, 120 grains per hour.

London gas, with a burner consuming about 5 cubic feet of gas per hour, gives an average illuminating power of 15 standard candles, Liverpool gas 16, and the gas of other towns varies in quality so greatly that gaslight should never be employed as a standard of measurement unless its actual value has been determined. In France the measurement is usually made by comparing with the light of a Carcel lamp, burning 648 grains of pure oil per hour. An ordinary gas jet, burning $4\frac{1}{2}$ cubic feet per hour, is equal to $1\frac{1}{10}$ th of a Carcel light as above. A burner consuming 7 feet per hour is equal to 1.72 Carcel lights—taking 16-candle gas.

The intensity of the beam of electric light varies considerably according to the relative positions of

the carbons. Thus, if a carbon having a square section be placed so that its axis corresponds with the line of one of the angles of the other carbon, the beams of light in different directions will vary as much as the ratio of 38 to 287, and even when the axis of one carbon lies properly in a prolongation of the axis of the other, the beam will vary with the angle formed by the beam with the axis of the carbons. Thus it is stated that the beam at right angles to the axis has measured 970 candles only, whilst that measured at 45° with the axis of the carbons has been 2,000 candles. The light should, therefore, always be measured on a beam at right angles to the axis of the carbons.

Rumford's Photometer is one of those often used, and its simplicity recommends it to the practical electrician. It consists simply of a calico or other screen, in front of which, and about a foot from it, is placed, vertically, an opaque rod of any material, such as blackened wood. The lights to be compared, for example a candle and a gas jet, are placed at different distances from the rod, and the gas jet is moved until the shadow it casts from the rod upon the screen is equal in intensity to that produced by the candle, which will, of course, be much nearer to the rod. The intensity of a light diminishes as the square of the distance or in other words, *the intensity of the light is inversely proportional to the square of the distance*. Since the intensity of a light at twice the distance is one-fourth, and at three times the distance one-ninth, it

is obvious that if two sources of light, of which one is placed at a certain distance from a surface while the other is placed at a distance twice or three times as great, produce equal degrees of illumination, the illuminating power of the more distant light must be four or nine times as great compared with the illuminating power of the light which is nearer to the surface. From this it is clear that when two sources of light produce equal intensities of light upon two surfaces at unequal distances, their illuminating powers are in the ratio of the square of their distances from the illuminated surfaces.

Unfortunately, a difficulty is introduced in such work by the redness of a candlelight and the intense violet rays given off by the electric light. For electric light measurements it is found better to use Bunsen's photometer, which enables the intensities to be compared with greater accuracy than is possible by the use of the opaque rod and screen. The difficulty consists in the very different appearance presented by a shadow cast by the reddish candle, and that given from the brilliant electric light.

Bunsen's Photometer consists of a square wooden frame, over which is stretched a piece of white paper, having a circular grease-spot in the centre. When lights are to be compared, a straight line is drawn upon a flat surface, the paper screen is placed vertically upon it with its centre on a level with the two lights, which are arranged upon either side of

it. The stronger light is moved away upon the line until the grease-spot is not visible, and then as before, by measuring the distances between the lights and the screen and comparing them, the power may be accurately arrived at. A grease-spot is best made by dropping melted stearine upon the paper, removing it with a knife, and weakening the strength of the spot by passing blotting-paper on either side of it under a hot iron. If the spot be too strong, it will be difficult to arrive at a correct estimate of the values.

Equal advantages should be given to both lights. For example, if the electric light be thrown upon the screen from a parabolic reflector, the candle-light should be also provided with a similar backing. If the electric light be diffused, the candle light should also be diffused, and care is necessary to have the back, grounds, and sides near to the lights equal in colour or reflective power. Care is also necessary that the experiment be made in an otherwise dark place.

In the experiments undertaken by the Committee of the Franklin Institute, to determine the efficiency of the dynamo-electric machines placed in their hands, namely, the large and small Brush, the Wallace-Farmer, large and small, and one of Gramme's machines, care was taken, in order to make the measurements as accurate as possible, so to arrange the apparatus that no reflected or diffused light should fall on the photometer, and thus introduce an element of error.

The electric lamp was enclosed in a box open at the back for convenience of access, but closed with a non-reflecting and opaque screen during the experiments. Projecting from a hole in the front of the box was a wooden tube, 6 in. square inside and 8 ft. long, with its inner surface blackened to prevent reflection, thus allowing only a small beam of direct light to leave the box.

The beam of light passed into a similar wooden tube, placed at a proper distance from the first (about 30 ft.), and holding in its farther end the standard candle. This tube also held the dark box of a Bunsen photometer, mounted on a slide, so as to be easily adjusted at the proper distance between the two sources of light. A slit in the side of the tube enabled the observer to see the diaphragm and grease-spot. The outer end of the second tube was also covered by a non-reflecting opaque hood, and the room was, of course, darkened when photometric measurements were taken. The rigid exclusion of all reflected or diffused light is believed to be the only trustworthy method of obtaining true results, and will, no doubt, account in a great degree for the lower candle power obtained in these experiments than that given by many previous experimenters.

The difficulties encountered in the measurement of the light, arising from the difference in colour, were at first thought to be considerable, but further practice and experience enabled the observer to overcome them to such an extent, that the error

arising from this cause is inconsiderable, being greatly less than that due to the fluctuations of the electric arc itself.

The Franklin Institute Committee considered what advantage would be gained by using a larger source of light than the standard candle, but after making several experiments with gas flames and the oxy-hydrogen light, they determined to use a standard candle only, making corrections for any variations in the rate of consumption of 120 grains per hour.

In determining the light-giving power of the current produced by the different machines, a continuous run of from 4 to 5 hours was made, and great care was taken to keep the axis of the two carbons of the lamp in the same line. To facilitate observations, a lens was placed in the side of the electric lamp box, in line with the carbon points. The axis of the lens was at right angles to the beam of light going to the photometer, and an image projected upon a screen, from the lens, enabled the observer to note the condition of the carbon points without distressing the eye. Photographic views of the carbon points were also taken at the moment of making the photometric observations, and care was observed that, at the moment of making the measurement, there was no fluctuation or moving from side to side of the electric arc.

The first of the following tables exhibits the results obtained by the Franklin Institute from their photometric measurements of the lights from the Brush

TABLE SHOWING WEIGHT, POWER ABSORBED, LIGHT PRODUCED, ETC., BY DYNAMO-ELECTRIC MACHINES
TESTED BY A COMMITTEE OF THE FRANKLIN INSTITUTE, 1877-8.

Name of Machine.	Weight.	Copper Wire in		Revolutions of Armature per minute.	Horse Power.	Light in Standard Candles.	Foot-lb. Power consumed per Candle.	Size of Carbons.	Length of Carbon consumed per hour.
		Armature.	Field Magnets.			Total.	Per H. P.	+	
Large Brush .	lb. 475	in. '081	lb. 32	lb. 100	1,340	3'26	1,230	8'74	in. '34
Small Brush .	390	'063	24	'196	80	1,100	3'76	900	'58
Large Wallace .	600	'042	50	'114	125	800	—	823	—
Small Wallace .	350	'043	18 $\frac{1}{4}$	'098	41	1,000	3'89	440	'73
Small Gramme .	366	'059	104	'108	104	800	1'84	705	'55

TABLE EXHIBITING DIMENSIONS, WEIGHT, LIGHT POWER, AND HORSE POWER ABSORBED IN THE MACHINES
TESTED BY THE TRINITY BOARD, 1876-7.

Name of Machine.	Dimensions.			Horse Power Absorbed.	Revolutions per Minute.	Light produced in Standard Candles.		Light per H. P. (condensed).	Light per H. P. (diffused).	Sizes of the Carbons.
	Length.	Brth.	Hght.			Weight.	Condensed.			
Holmes	in. 59	in. 52	in. 62	lb. 51	3'2	400	1,523	4'76	8 $\frac{1}{2}$	8 $\frac{1}{2}$
Alliance	52	54	58	36	3'6	400	1,953	5'43	5 $\frac{1}{2}$	5 $\frac{1}{2}$
Gramme (No. 1) . .	31	31	49	25	5'3	420	6,663	4,016	1,557	758
(No. 2)	31	31	49	—	5'11	420	6,663	4,016	1,257	758
" Siemens' (Large) . .	45	29	14	11	74	9'8	14,818	8,932	1,512	911
" (Small)	26	—	10	3	84	3'3	850	6,864	4,138	2,980

* In this table, as it appears in Mr. Donglass's report to the Trinity Board, dated April 31, 1877, these columns are headed "Condensed Beam" and "Diffused Beam." In the copy of the same table as given in Mr. Donglass's paper, read at the Institute of Civil Engineers, March 25, 1879, the same columns are headed "Maximum" and "Mean" respectively.

machines, large and small; the Wallace-Farmer machines, large and small, and the small machine of Gramme, made by Breguet, and sent by him to the Philadelphia Exposition. The latter machine was lent by Prof. Wiley, of Purdue University, Lafayette, Indiana, and the others were sent in by their makers—the Brush by the Telegraph Supply Company of Cleveland, Ohio, and the Wallace by Wallace and Sons, of Asonia, Conn. The second table gives some particulars of the experiments made at the South Foreland by Mr. Douglass, the engineer to the Trinity Board, in 1876 and 1877.

The measurements of electric lights made by the Franklin Institute, and those by the Trinity House authorities, thus include particulars of the chief machines at present in use.

It is but fair to the proprietors of the Gramme machine, as tested by the Trinity Board, to state that the type of apparatus tried was not the best in use, and that the Gramme has since been found in practical working to very nearly reach the candle power per horse power of the smaller Siemens, while it is more compact.

According to Messrs. Sautter and Lemonnier and Co.'s experiments, made by them in Paris, they give for the Gramme machines:—

A type 2,400	}	Standard candles per H. P.
C type 2,800		
D type 3,125		

The superiority of the Siemens and Gramme machines over all other inventions yet in use in

England and America is not difficult to find a reason for when the constructional details are examined. These machines are also cool in working. As far as the author can learn, the new dynamo-electric machine invented by Weston, being somewhat similar in construction to the Siemens apparatus, runs both Siemens' and Gramme's machines very closely in point of efficiency, and it is one of the coolest machines in use—there is, however, a slight loss over churning the air.

In the photometric measurements of the Trinity Board, the standard of comparison was the 6-wick colza-oil lamp of the Board, and it was placed at a distance of 100 feet from the electric lamp. It was found that when two of Siemens' machines were coupled together, they gave a larger candle power than when worked separately. Working separately the aggregate light was equal to 12,403 candles, while the illuminating power rose to 14,134 candles when the machines were joined to one cable and driven at the same speed as before.

CHAPTER X.

MATHEMATICAL AND EXPERIMENTAL TREATMENT OF THE SUBJECT.

Dr. Hopkinson's Investigations.—Dr. Hopkinson, in April, 1879, read a valuable paper on “Electric Lighting” before the Institution of Mechanical Engineers. In this communication he gives the results of experiments on one of Siemens’ continuous current dynamo-machines to establish the relation between the electro-motive force, resistance of the circuit and current, and also between the energy transmitted, measured by dynamometer, and that appearing as current. The curve formed by taking the current as abscissæ and the electro-motive force as ordinates when different resistances are in circuit, is given, the quantities being reduced to a common rate of 720 revolutions a minute, it being taken that electro-motive force, with the other elements constant, is proportional to the speed. From this curve various problems can be solved. It will determine what current will flow at any given speed of rotation of the machine, and under any conditions of the circuit, whether of resistances or of opposed electro-motive forces.

Mr. Schwendler's Experiments.—With regard to the relation of speed to currents and electro-motive force, Mr. Schwendler* states: "The current produced by a dynamo-electric machine through a given constant total resistance in circuit increases permanently with the speed of the induction cylinder. This increase of current for low speeds is more than proportional to the speed, afterwards it becomes proportional, and for high speeds the increase of current is less than proportional to the speed. The current has, however, no maximum for any speed, but reaches its greatest value at an infinite speed. This same law, as the total resistance in circuit is supposed to be constant, of course holds good also for the electro-motive force."

With regard to the influence of external resistance, Mr. Schwendler further states: "Keeping the speed constant, the electro-motive force decreases rapidly with increase of external resistance. This decrease is more rapid the smaller the internal resistance of the machine. Hence the currents must decrease much more rapidly than proportional to the total resistance in the circuit. As in the case of speed the electro-motive force has no maximum for a certain external resistance, but approaches permanently its greatest value for an external resistance equal to nil."

Mr. W. H. Preece's Investigations.—Mr. W. H.

* Précis of report to the Board of Directors of the East India Railway on electric light experiments.

Preece, in a paper on the Electric Light in the *Philosophical Magazine* of January, 1879, investigates mathematically the question of grouping lights in multiple arc and in series, and arrives at the conclusion that "beyond certain limits when the current is produced by a dynamo-machine if n lamps be joined in series the total light becomes diminished by $\frac{1}{n}$, and the light emitted by each lamp becomes diminished by $\frac{1}{n^2}$. If they are joined up in multiple arc the total light is diminished by $\frac{1}{n^2}$ and the light emitted by each lamp $\frac{1}{n^3}$. In the latter case the rapid diminution in the light emitted is due to the fact that the heat is developed in the machine itself instead of in the resistances external to it."

Mr. Preece then goes on to say, "We have assumed w (*i.e.* the work done in the steam-engine in unit time) to be constant; but this is only the case when the velocity of the rotating coils in the dynamo machine has attained a maximum. This limit will vary with each dynamo machine and each kind of lamp used. With the Wallace-Farmer machine the limit appears to be reached when six lamps are connected up in series. With the Gramme alternating machine and Jabloch-koff candles the limit appears to be five lamps. Beyond these limits the above laws will be true. It is partial success in multiplying the light that

has led so many sanguine experimenters to anticipate the ultimate possibility of its extensive subdivision—a possibility which this demonstration shows to be hopeless, and which experiment has proved to be fallacious."

Mr. Alexander Siemens' Paper at the Society of Telegraph Engineers.—Mr. A. Siemens has pointed out, in a paper read before the Society of Telegraph Engineers in March, 1880, that in the ordinary dynamo machines as generally used, "the intensity of the magnetic field in which the armature revolves varies very much, being greatest when the external resistance is smallest, and *vice versa*. If therefore the lamps producing the light are not working very regularly, their action re-acts continually on the machine in the most unfavourable way, by weakening the magnetic field when the resistance is greatest and the current most wanted, and by inducing the most powerful currents when the least resistance is to be surmounted." This often destroys the insulation of the wire.

To obviate this the electro-magnet circuit has been made a parallel circuit to the external resistance circuit, one circuit acting as a shunt to the other. In this case, as the external resistance increases the E. M. F. rises, as more current passes through the electro-magnet circuit.

But although this causes the E. M. F. to vary in the right direction it still causes fluctuation, and the variation in the strength of the field magnets causes a variation in the power absorbed, and

also displaces the most favourable point for the brushes.

A constant and permanent magnetic field is therefore recommended by using a separate machine for exciting the electro-magnets.

It is also pointed out that length of leading wires, by adding to the resistance of the circuit, diminishes the fluctuations in the current caused by the variation in the resistance of the arc.

Alternate current machines appear, according to Mr. Siemens, to stand wear and tear better than the continuous current machine, and in those made by Mr. Siemens an important improvement has been introduced by omitting the iron cores of the revolving coils. The heating effects of the cores caused by the incessant reversing of their polarity is thereby avoided, and the intensity of the magnetic field scarcely affected.

Mr. Fitzgerald's Investigations.—It has been remarked by so able an investigator of electrical phenomena as Mr. Fitzgerald, that there is no force in nature varying simply as the number of cells in series of a battery or corresponding with what is known as electro-motive force, and no inertia varying according to what is defined as electrical resistance.

Further, it is observed that the effects of varying those "current elements" are very different in the two cases of the dynamo-electric and the voltaic currents. The law of Ohm, as previously applied to the current effects of voltaic batteries, was thought

by some to be inapplicable in certain points to the dynamo-electric machine and its currents. This does not mean, however, that the well-known law of Ohm is incorrect as a law of phenomena—an expression indicating a necessary relation—but from a physical point of view as empirical as other mathematical laws in which causation is lost sight of.

In the case of any electro-motor the equation $I = \frac{E}{R}$ is perfectly applicable. In the voltaic battery, however, a variation of R does not of necessity affect E , which is altogether independent of such variation when this occurs in the external portion of the circuit. Thus we have generally $I \propto \frac{E}{R}$, or current varies inversely as the resistance in circuit.

A variation of E does not necessarily affect R ; and, when the external resistance of the circuit bears a high ratio to the battery resistance, a variation of the electro-motive force from E to E' —an addition to, or diminution of, the number of cells in series—causes the current to vary approximately in the ratio $\frac{E'}{E}$. Accurately, the variation in any case is determined by the ratio $\frac{E' R}{E R + E \rho}$, where ρ is the resistance of the cells added or subtracted. Thus,

$$\frac{E}{R} \times \frac{E' R}{E R + E \rho} = \frac{E'}{R + \rho}.$$

In the case of a telegraph circuit, for instance,

we have approximately $I \propto E$. On the other hand, in the dynamo-electric machine, converting into electrical work a given horse-power, $I \propto \frac{1}{\sqrt{R}}$, since,

the ratio $\frac{E^2}{R}$ being constant, $E^2 \propto R$, $E \propto \sqrt{R}$, and

$\frac{E}{R} \propto \frac{\sqrt{R}}{R} = \frac{1}{\sqrt{R}}$. Thus any variation of R in this case necessarily affects E .

Again any variation of E necessarily affects R ; and, the product $E I$ being constant, we have

$I \propto \frac{1}{E}$, a somewhat startling result, which, to some observers, has appeared contradictory to the law of Ohm. With this, however, it is in perfect accord—in effect, since $E \propto \sqrt{R}$, $R \propto E^2$, and

$$\frac{E}{R} \propto \frac{E}{E^2} = \frac{1}{E};$$

or, when E is varied, the current varies inversely as the electro-motive force, because the resistance varies as the square of this value.

It will be seen that $R \propto E^2 = \frac{1}{I^2}$, and that the same quantity of work will be done by the current whatever may be the resistance in the circuit.

If h. p. be taken to express the total horse-power converted into electrical work (in the whole circuit), under the best conditions, with a Gramme machine of the form experimented with at the Franklin Institute,

$$\text{H. P.} = \text{h. p.} \times 1.39,$$

and the efficiency of the machine is expressed by

$$\frac{\text{h. p.}}{\text{H. P.}} = .72 \text{ (nearly).}$$

Or the machine can convert into electrical work 72 per cent. of the energy expended upon it.

Let E = electro-motive force, in volts, acting in a circuit.

R the total resistance, in ohms, of the circuit.

r = resistance of the voltaic arc obtained.

$H. P. = h. p.$ of the prime motor working the dynamo-electric machine.

$h. p. =$ the $h. p.$ absorbed in the production of electrical work in the circuit.

λ = the intensity, as standard candles, of the electric light so arranged as to illuminate equally in all directions.

Λ = intensity of the light in one particular direction; the light being arranged to give the maximum illumination (without reflectors) in this direction.

The energy of the current, or the mechanical equivalent of the work and heat produced by it *per hour*, will be

$$W = \frac{E^2 \times 2654}{R} \text{ ft.-lbs.} = \frac{E^2 \times 1.18}{R} \text{ ft.-tons.}$$

Horse-power absorbed in the current

$$\left(\frac{\text{energy in ft.-lbs.}}{33,000 \times \text{time in min.}} \right)$$

will be

$$h. p. = \frac{E^2}{R \times 747}.$$

The ratio $\frac{\text{h. p.}}{\text{H. P.}}$ is the measure of the efficiency of dynamo-electric machines. In the case of Gramme's machine, under the best conditions we have

$$\text{H. P.} = \text{h. p.} \times 1.39.$$

The horse-power absorbed in the arc itself is

$$\text{h. p.} \times \frac{r}{R}$$

The ratio of this latter value to h. p., or

$$\frac{r}{R} = \frac{\text{h. p.} \times r \times 747}{E^2}$$

is the measure of the efficiency of the electrical circuit in the production of the greatest quantity of light with a given quantity of electrical energy.

In the experiments with the Gramme machine made by the Committee of the Franklin Institute, the light, in standard sperm candles, produced by the voltaic arc was

$$\lambda = \text{h. p.} \times \frac{r}{R} \times 1,044 \text{ (candles)} \dots (I)$$

when the intensity of the light was approximately equal in every direction. But, when the carbons are so adjusted as to give the best effects with the photometer in a given position, we may multiply the former value by 2.87, and we have

$$\Lambda = \text{h. p.} \times \frac{r}{R} \times 2,996 \text{ (candles)} \dots (II)$$

Expressing these equations in a different form, we have

$$\lambda = I^2 r \times 1.4 \dots (Ia)$$

$$\Lambda \times I^2 r \times 4 \dots (IIa)$$

It should be remembered that these values are obtainable only under the most carefully arranged conditions.

Although the light cannot be subdivided without very considerable loss, it is not to be admitted that, if a given total quantity of light be produced with one hundred lamps, it is one hundred times as expensive as if it were produced by one lamp. If we use two lamps instead of one, and put them in series, the original arc resistance, l , is not necessarily doubled; indeed it may be preserved constant, in which case we should have $\frac{C^2 l}{2}$ for each light, and the original value, $C^2 l$, for the two. And if we place four lamps in parallel circuit, the total resistance may be reduced nearly fourfold, so that we may obtain twice the original current with half the electro-motive force in action. Thus

$$C^2 l, \text{ or } \frac{E^2}{l^2} l \text{ becomes}$$

$$\left(\frac{E}{2}\right)^2$$

$$\left(\frac{l}{4}\right)^2 \times \frac{l}{4} = \frac{4 E^2}{l^2} \times \frac{l}{4} = C^2 l.$$

The theoretical value for each light being

$$\left(\frac{C}{2}\right) l = \frac{C^2 l}{4},$$

and that from the four $C^2 l$. The loss, when the light is subdivided, is doubtless due to an increase in the quantity of heat which must be expended before any luminous effect is produced.

Equational numbers required in reducing results.— The particulars given herewith will be found of value in any experiments upon dynamo-electric machines, circuits, or lamps.

One horse-power is equal to 1,980,000 foot-lbs. per hour, or 33,000 per minute; that is, 33,000 lbs. weight falling one foot in a minute, or 1 lb. weight falling 33,000 feet per minute.

1 horse-power is maintained in modern steam-engines with $3\frac{1}{2}$ lbs. of coal per hour.

1 heat unit = 772 foot-lbs.

Therefore, 1 horse-power = 2,565 units of heat per hour, and $\frac{2565}{772} = 6\frac{1}{4}$ units of heat per candle of light.

1 standard candle (of sperm) burns 120 grains per hour, and equals $\frac{1}{3}$ cubic feet of gas per hour.

1 lb. gas coal produces 4 cubic feet of gas, 0.85 lb. of gas coke, and 0.05 lb. of tar. In a pound of gas coal there are 15,000 units of heat, in the coke 13,000, in the gas tar 20,000 units of heat.

The power expended by a dynamo-electric machine producing current for the light of a standard candle is about 90 lbs. falling through one foot in a minute.

1 calorie (kilogramme of water heated 1° Centigrade) is equal to 424 kilogrammètres, which equals 3.9683 units (Fahrenheit).

1 kilogrammètre equals 7.2331 foot-lbs.

CHAPTER XI.

PRESENT APPLICATION AND COST OF THE ELECTRIC LIGHT.

So extensive has been the introduction of electric lights that to enumerate and dwell upon them in detail would in itself almost fully occupy the pages of this little treatise. The more noteworthy instances can only, therefore, be briefly glanced at.

Interior Illumination of Large Buildings.—Such places as theatres, before and behind the scenes, halls, and picture-galleries, are most effectually illuminated from above. There are various ways of doing this, and of diffusing the light. Perhaps the best is that of sending the full rays through a large sheet of frosted glass.

This should be set in the centre of the ceiling, if convenient at the same height as the ceiling. Its size will depend upon the size of the building. For a medium-sized theatre, a glass surface 6 feet square will be found sufficient. Directly above this frosted glass surface is to be placed the electric light. The lamp should be hung by a cord and counterpoise, and if it be of the form described at page 207, no other arrangement will be necessary,

because the rays of light from this lamp are all thrown downwards. If another form of lamp be used, it will be necessary to reflect the light downwards from it by means of wooden covers, about 6 feet square, covered with sheets of tin plate. Two of these will be found sufficient. They should be set at an angle, rising from the edges of the frosted glass until quite over the lamp. Any rays then thrown upwards will be reflected upon the frosted glass.

Light sent over a building in this way is beautifully diffused, and is very soft and agreeable. It will be necessary to have free access to the lamps from above. In some cases it will be found very advantageous to enclose the lamp in a ground-glass case, and to suspend this near to a white ceiling. But a better plan still is to have a pyramidal case of ground-glass made, to fasten the base of this to the ceiling, and to lower the lamp into it from above. The result is perfect diffusion of the light, which must of course be reflected downwards into the glass case by reflecting boards or a whitened ceiling.

Workshops are usually illuminated by setting the lamp over a reflector on the floor, screened by some cover, and projecting the rays from the reflector upon the white-washed ceiling. This is what is usually done, and is found to answer the purpose very well. A great objection to the Serrin and such lamps is the base containing the movement, which, when the lamp is suspended, throws

downwards a great deal of shadow; but this is entirely prevented by the use of slanting reflectors.

In the extensive chocolate works of M. Menier the Serrin lamps are in use, and the proprietor has devised a means of access to the suspended lamps without the use of ladders or a separate suspension cord. A windlass is used, having a dry wooden drum with cast-iron cheeks. A cable with two insulated and stout wires is made fast to the drum, and the ends of it to the cheeks; this cable leads upwards to the roof, over a pulley, and on the other side hangs the lamp. It can thus be lowered by the windlass with ease without in any way disturbing the connections. The cheeks of the winding drum are, of course, connected to the terminals of the dynamo-electric machine through the separated bearings.

Electric lights are in extensive use in all out-of-door works of magnitude, such as bridge and dock construction, and it is found, as was proved in the case of the great Tay bridge, that operations may be carried on at night with the greatest facility. For such purposes, the light should be so arranged that a power of about 2,000 candles is thrown around every 600 feet of space—that is, an ordinary 2,000 electric light, placed upon a 20-feet standard, should give sufficient illumination at a radius of 300 feet. In some cases the standard is thus inadmissible, and the light may have to be thrown upon the work from a parabolic reflector. All such lights

should be enclosed simply in a clear glass case to screen them from the wind.

The use of ground-glass cases for these purposes, and above all opalescent glass of any density, should be avoided as much as possible. A great deal of light is thus lost in the Jablochhoff system. It has been found from experiment that

Plain glass absorbs about	10 per cent.
Ground or frosted	30 "
Thin opalescent	45 "
Thick ditto	60 "

A great deal has been said as to the evil effects of the electric violet rays upon the eye. Such rays do apparently injuriously affect the eye more quickly than the yellow ones from gas, but there is no reason why persons using the electric light should stare at it any more than at the sun itself, both being hurtful to the naked eye direct, but not otherwise. The use of reflection is, however, advisable, since the blue effect given by direct rays proves so annoying to the eyes.

When the light is any considerable distance from the machine the cables carrying the current should be thick and of good copper, and every means thus used to reduce the resistance of the conductor outside the machine, more especially when a lamp with long carbons, and consequently much resistance, is employed.

The use of the electric light in our lighthouses is a matter of great importance, but not of special interest to the general public, so that, with the

exception of what has been said in connection with the experiments on dynamo-electric machines, it need not further occupy space.

For use aboard ship, and for war vessels especially, a very useful apparatus is manufactured by Messrs. Sautter and Lemonnier. It is a lenticular projector, with a Fresnel lens, composed of three dioptric and six catadioptric lenses. The Serrin lamp is placed behind the system, which is mounted on an iron stage, movable around its vertical axis, and turning upon its horizontal axis, so that the light has great range, and may be concentrated upon one point anywhere around the vessel. The whole is enclosed in a cylinder, opaque behind; and a small camera lucida is so placed in it as to throw the image of the carbon points upon a ground-glass screen, so that their condition may be noted without opening the cylinder. The three-cylinder Brotherhood direct engine is usually employed to drive the machine in conjunction with such apparatus. Mr. Wilde has supplied most of the machines and lamps for our navy, and Mr. Siemens for the War Office.

Cost of Electric Light.

In entering upon a consideration of this aspect of the question, the greatest care is necessary in order that the data may be of a thoroughly trustworthy character.

Reports by interested companies or persons are almost always biassed, so that, as may be inferred

from a perusal of any one instance, little trust can be placed in them.

The Gaslight and Coke Company, whose works are at Westminster, tried the electric light to test the question of cost. Their experiment was carried on for 1,000 hours; they used a 6 horse-power engine, which cost 1s. 6d. *per hour for fuel alone*—that is, about 40 lbs. of coal *per horse-power per hour*: this engine must have been singularly inefficient. The light produced from a Siemens' machine was of 2,000-candle power, and in their experiment replaced 4 sun-burners of 63 jets each, consuming in the aggregate 760 feet of gas per hour. The result is that they give the cost of the electric light as double that of the gas. Very little consideration of the following figures will suffice to show what this light ought to have cost the gas company. It cost them 4s. 6d. per hour, while any electrician will undertake to produce a light of double the power at 1s. 10d. per hour, in continuous work.

This is a case in point, the facts of which the public are free to investigate as far as the report goes.

On the other side another case of actual application may be mentioned. At the St. Lazare station of the West of France Railway there are six electric lights of 480-candle power each, on the Lointin system. They are produced by the power from a common agricultural engine with 9½-in. cylinder of 13½-in. stroke. The carbons for the lamps cost

altogether 8d. per hour, and the real working expenses are :—

	s. d.
Coal at 32s. per ton	1 2
Carbons	0 8
Attendance	0 10
Per hour	2 8

This is for six electric lights, in aggregate power 2,880 candles. Let this be compared with 4s. 6d., the cost of a 2,000-candle light with coals at 20s. per ton as above.

In numerous other such cases may the facts be learned, where the light has been in use for years (since 1877), and in every application where the arrangements are properly carried out, and where the light has replaced gas or oil, except in street lighting alone, the price is greatly in favour of electricity.

The cost of illuminating the streets by gas is, as is generally known, exceedingly low, especially in London, and this, of course, told against electricity when an attempt was made to introduce it for that purpose.

To put down new plant and electrically light a street, then to compare the cost with that of gas at street price, is obviously not consistent with ordinary fair working : and this is what was done in Paris, and in High Holborn, nearer home. Gas has been established for years, has every advantage of long experience in working, it comes from a manufactory where the quantity produced renders the supply to one street very insignificant in point

of cost, and yet it was thought to be a wise thing to place electricity side by side with it and compare the costs. It will not yet pay, as far as experience has shown, to light only one street by electricity ; it must be done upon a larger scale or not at all.

Gas for private users costs so much that, in the case of workshops, yards, theatres, picture galleries, and numerous other places where there is real work for a surpassingly brilliant and powerful light or two, electricity is without the shadow of a doubt the cheaper, not to speak of its additional advantages, and the fact that colours are not falsely represented by it as by gas light.

Where electricity replaces gas at 2s. 9d. per 1,000 cubic feet, a saving will undoubtedly be effected, even as the light now stands, not to speak of greater perfection, which will assuredly be attained.

For the splendid illumination of *skating ponds* and *pleasure grounds* at night, the electric light is not by any system expensive, because the same effects could not at any cost be obtained by gas or oil lamps.

In almost every case of street illumination the Jablochkoff candle has been used. This necessitates the production of alternating currents, and alternating currents are extremely wasteful of power in long circuits. If a good direct system were tried, there is every prospect that street lighting by electricity would prove itself at least as cheap as gas, while fewer lamps and fittings would be needed, and a better light secured.

Let the various expenses in establishing apparatus for the production of one electric light by the open circuit method, or six, by a method such as Werdermann's, and of 5,500-candle power, be tabulated at the highest figures of to-day:—

	£	s.	d.
One dynamo-electric machine of 6,000-candle power .	75	0	0
The most expensive lamp in use, or 6 incandescent lamps, with cables and fittings	25	0	0
One 6 horse-power steam-engine and boiler, complete	150	0	0
Cost of Plant .	<u>250</u>	0	0

WORKING EXPENSES.

(Per year, of 1,200 hours' working.)

	£	s.	d.
Interest on cost of plant, say	15	0	0
Wear and tear in machine and lamps	8	0	0
", engine and boiler	12	0	0
Labour, attending to engine, machine, and lamps at 7d. per hour (one year of 1,200 hours)	35	0	0
Fuel at 4 lbs. per horse-power per hour, with coal at 20s. per ton, say 24 tons	24	0	0
Carbons for the lamp	25	0	0
Oil, and other items	5	10	6
Cost of a 5,500-candle light for 1,200 hours	124	10	6

Such a light should replace, in most applications, over 400 gas jets burning 5 cubic feet per hour each, the cost of which, at 3s. per 1,000 cubic feet, would be 6s. per hour, or about, for 1,200 hours light, £350.

The prices quoted for plant will be found higher than the actual prices, and those given for working expenses will also be over the average in most places in England; while the price of gas considered is lower than the average in England.

The cost of an outfit to give a 1,200 candle light is £180:—

	£	s.	d.
5 horse-power engine and boiler complete . . .	100	0	0
Dynamo-electric machine and lamp, with fittings . . .	80	0	0
	<u>180</u>	<u>0</u>	<u>0</u>

Dynamo-electric machines and lamps are becoming cheaper as time goes on and as competition is beginning to be felt, and a higher return for power expended may yet be expected.

Outfits for the exhibition of electric lights as advertisements or otherwise are easily to be had on hire, at low enough charges.

The places where the electric light may now be seen in constant use are so numerous that to quote particulars of the cost would involve a recapitulation of what has been already said.

The cost of illuminating by voltaic generators is always high, but for short displays this is compensated for by the convenience.

Mr. A. Siemens, in his paper read before the Society of Telegraph Engineers, March, 1880, gives the following particulars as regards comparative cost of electric light and gas. In making the comparison it is assumed that a hundred-candle Sugg gas-burner will consume 23 cubic feet of gas per hour, costing 3s. 6d. per 1,000 cubic feet: further, that a 400-candle alternate current light requires $\frac{1}{2}$ horse-power, and that it consumes 3 inches of carbon per hour, costing 4½d. per foot; and that a 6,000-candle continuous current light

requires 4 horse-power, consuming 3 inches of carbon per hour, costing 8d. per foot. When the electrical machines are driven by a gas engine consuming 26 cubic feet of gas per hour per horse-power, the relative cost of maintaining a light of 6,000-candle power is as follows:—

For gas 4s. 10d.

For alternate current electric lights (fifteen 400-candle lights) :—

	s.	d.
200 cubic feet of gas for the motor	0	8½
3 feet 9 inches of carbon, at 4½d. per foot	1	4½
Attendance	6	
	<hr/>	<hr/>
	2	7

Showing a saving of 47 per cent. over gas.

For continuous current light :—

	s.	d.
114 cubic feet of gas for the motor	0	4½
3 inches of carbon, at 8d. per foot	2	
Attendance	1½	
	<hr/>	<hr/>
	0	7½

Showing a saving of 87 per cent. over gas.

At the Albert Hall a saving in gas is effected of 25,000 cubic feet per night, or £4 7s. 6d., while the five electric lights cost £1 10s. 6d. for fuel, attendance, and carbons. In this case a pumping engine is used for driving the machinery, which consumes a very large quantity of fuel, and nevertheless a saving of 66 per cent. is effected.

At the British Museum the electric light was used for 360½ hours between 28th Oct., 1879, and the end of February, 1880. Two 8 horse-power engines

are used. There are four lights in the reading room, of 4,000 candle power each, and in the halls seven of 400 candles each. There are four continuous current machines for the reading room lamps, one to each lamp, in separate circuits. One alternate current machine works the other seven lights. Another machine of continuous current type excites the electro-magnets of all the other five. The machines are tried in the morning, and then the fires of the engines are banked up so as to be ready at 10 minutes' notice.

The cost for 360 hours is as follows:—

	£	s.	d.
Carbons	50	15	10
23 tons of coal, at 15s.	17	5	0
18 gallons of oil, at 4s. 6d.	4	1	0
54 lbs. of waste, at 6d.	1	7	0
2 sets of brushes, at 5s.	0	10	0
1 set of commutator plates	0	17	6
Engine-driver, 18 weeks at 37s.	33	6	0
Total cost	<u>£</u>	<u>108</u>	<u>2</u>
		<u>4</u>	

This gives us cost per hour:—

	s.	d.
For carbons	2	9
Other charges	3	3
	<u>6</u>	<u>0</u>

for a light of 18,800 candles; which amount of light produced by gas would cost at least 15s. per hour, the saving effected being 60 per cent.

The following facts as to the lighting of the Thames Embankment will be of interest. The first

experiment with 20 lights was commenced on the 13th of December, 1878, the second with 40 on the 16th of May, 1879, the third with 55 lights on the 10th of October, 1879. The length of the circuit on the west side of Waterloo Bridge is 6,007 ft.; of that on the east side 6,062 ft. The total length of conducting wire is 17 miles 361 yards. The ten new lights on Waterloo Bridge are worked by a 20-light Gramme machine in two circuits.

The following are a few particulars of Messrs. Siemens' machines, &c.:-

Alternating current machine, large size.

Dimensions, $29\frac{1}{2}'' \times 27\frac{1}{2}'' \times 34''$.

Weight, 8 cwt. 0 qrs. 13 lbs.

Speed, 600 revolutions per minute. Price £ 137

Small dynamo-machine for magnetising the above. Speed

1,000 revolutions per minute. Price 45

£182

Capacity for 12 lamps in one circuit, or two circuits of 6 lamps each. Each lamp of 400 candle power. Total power absorbed about 9 horse-power.

Smaller alternating current machine.

Dimensions, $28'' \times 19\frac{1}{2}'' \times 24''$.

Weight, 5 cwt. 0 qrs. 20 lbs.

Speed about 700 revolutions per minute. Price £ 87

Small dynamo-machine for magnetising 38

£125

This machine feeds 6 lamps of 400 candles each in one circuit, and absorbs 5 horse-power.

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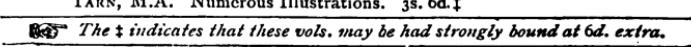
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